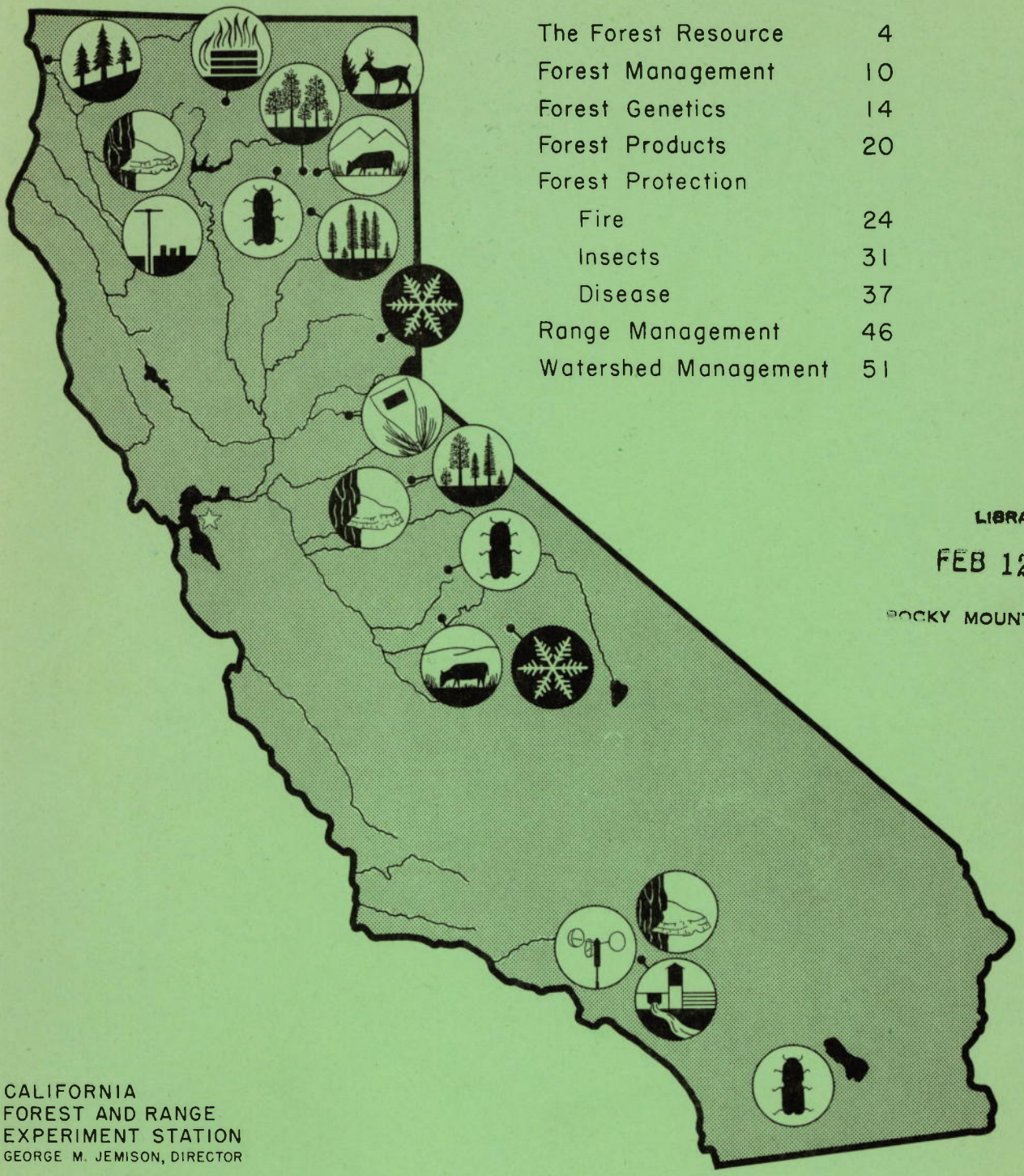
ANNUAL REPORT · 1956

FOREST RESEARCH IN CALIFORNIA



CALIFORNIA
FOREST AND RANGE
EXPERIMENT STATION
GEORGE M. JEMISON, DIRECTOR

FOREST SERVICE — U. S. DEPARTMENT OF AGRICULTURE

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
CALIFORNIA FOREST AND RANGE EXPERIMENT STATION

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R-CAL
REPORTS
Station's Annual

March 20, 1957

Dear Sir:

I am enclosing a copy of this station's annual report for 1956. This year, besides reporting some highlights of our work, we have tried to bring into sharper focus our efforts to keep the station's program oriented towards demands for new information that are resulting from California's continued economic growth.

Some of the more important adjustments in the research program that this report describes are:

A stronger attack on the problems of improving water yield from the winter snowpack.

Expansion of forest management studies into the red fir and redwood--Douglas-fir timber types, and a start on timber marketing studies.

Additional basic studies in the fields of tree seed production and forest planting.

A more comprehensive attack on forest protection problems, including fire, insects, and disease.

The growth of cooperative projects has aided these changes substantially. Among our newer cooperators are the California Department of Water Resources, the Simpson Redwood Company, and the University of Southern California. And we have continued to benefit from the financial and technical aid of the California Division of Forestry, the University of California, the California Department of Fish and Game, California Institute of Technology, the Forest Genetics Research Foundation, and Resources for the Future.

We believe these developments will help keep the research program in harmony with growing demands on the region's natural resources, and we recognize the need for constant adjustments in some aspects of the program. I hope you will find this account of recent developments of interest, and I shall be happy to have your suggestions for improvement or comments on our activities.

Very truly yours,

George M. Jemison

GEORGE M. JEMISON, Director

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RESEARCH FACES NEW FOREST AND RANGE NEEDS

Last year we described the impressive growth of California and the impacts of current and future changes on timber, water, range, and wildlife resources. Such changes require constant adjustment in some aspects of a research program. Furthermore, they call for a good deal of foresight if we are to develop a program most directly geared to long-term trends. We have tried to keep our research in harmony with the continuing expansion of agricultural, industrial, and domestic activities in the State and with the growing demands on the forest resource.

NEW COOPERATIVE PROJECT SEEKS MORE WATER FROM SNOW

One significant change is the start of a major cooperative study in snowpack management. This was made possible by the matching of federal funds with those of the California Department of Water Resources. The need for a study of this kind was underlined by the California Water Plan, presented to the people and discussed widely during the year. This plan would require eventual capital expenditures of nearly 13 billion dollars. It would build 260 major structures, add 60 million acre-feet of surface storage capacity to the existing 20 million acre-feet, permit more intelligent utilization of groundwater storage resources, and carry many other benefits. The manner in which California's watersheds are developed and managed will have a profound effect on the future water supply envisioned under the California Water Plan. Significant is the fact that 95 percent of our annual runoff comes from the wildlands: timber-, brush-, and grass-covered watersheds. About half originates from the snowpack in the high mountains of the State.

Snowpack research studies will investigate the relations between forest vegetation and water quality, yield, and timing of runoff from the snow-covered watersheds. A new section has been set up in our Division of Watershed Management Research and seven technical workers are already on the job.

PROGRAM SHIFTS TO MEET NEW TIMBER INDUSTRY NEEDS

The large timber industry in California is undergoing major changes. A trend toward consolidation of ownerships is evident in some parts of the state. More and more interest in complete utilization in the woods and in the mills is apparent. Construction was started or plans were completed for two new pulp mills during the year. The demand for better information on timber management and utilization is growing and will intensify as market opportunities develop. Specifically, both public and private land managers want to know...

...how to make better use of timber they harvest
...how to get better growth from existing forests
...how to utilize species heretofore neglected
...how to market new products and species
...how to put idle land to work.

The Station's program is being gradually shifted to meet these trends. Near the end of the year we started a cooperative timber management and utilization research program at the Yurok Redwood Experimental Forest in cooperation with the Simpson Redwood Company. The first work there will be on old-growth redwood problems. The Swain Mountain Experimental Forest, an area primarily timbered with red and white fir, has been opened and experimental cutting will start next spring. Plans have been developed for a management-utilization research program in the mixed-conifer type of the West Sierra, but no means are presently available to start this work.

One obstacle to more intensive management and the utilization of more species and sizes than are now merchantable is the lack of adequate markets. A small start has been made to investigate some of the marketing problems that exist. A broad study of log and tree grades is getting underway. This investigation will supply needed information on quality standards and will be basic to further progress in utilization.

Last year we described how planting the best of California's 4.1 million acres of non-stocked or partially stocked land would broaden the raw material base and add to our net timber growth. Over the years, tree planting in the state has been beset with many problems. This year a modest increase in forest management research funds enabled us to begin with new emphasis an attack on some of the basic stumbling blocks.

In cooperation with the California Institute of Technology we started research on the physiology of pine seedlings. We believe these studies will lead to new understanding of tree seedlings' root development, their optimum temperature and moisture requirements, and similar fundamental considerations.

NEW RESEARCH CENTER OPENED IN NORTHEASTERN CALIFORNIA

To knit the existing forest and range investigations in northeastern California into a closely coordinated unit, the Station set up a research center at Susanville in September. Its program embraces the silvicultural work at Blacks Mountain Experimental Forest that has been underway since 1936, the new program at Swain Mountain, range management studies on the Harvey Valley cattle allotment, and game-range rehabilitation studies. The investigations of game-range problems conducted in cooperation with the California Department of Fish and Game, have been strengthened by new Forest Service funds.

Additions to the range research program at the San Joaquin Experimental Range in cooperation with the University of California are also contemplated. Seasonal, rotational, and intensity of grazing studies in the important annual grass type of the foothills will be started. The current program of range fertilization and reseeding will be incorporated in the tests of grazing management.

FOREST PROTECTION RESEARCH STRENGTHENED IN THREE FIELDS

Several fire research activities were given new or additional emphasis during the year. Besides Station research in forest fire prevention, we started fire prevention studies with the School of Public Administration, University of Southern California. The Helitack program, seeking more effective use of helicopters in fire control, was started. Chemical fire control and some aspects of aerial delivery of fire retardants were tested, again with substantial cooperative assistance. Yet in spite of a small increase in regularly appropriated funds, fire research suffered a net loss during the year when the 7-year-old cooperative project with the Department of Defense was put on a close-out basis. Much new knowledge of ignition and fire behavior has been gained under this program.

We continued to make progress toward solving the serious insect and disease problems of the state that result in a kill of hundreds of millions of board-feet of timber each year. New and effective work on insect-resistant pine hybrids was

started. Formation of a Pest Control Division in the administrative branch of the Forest Service, freed the Station of responsibility for technical supervision of control work and widened opportunities for research. The detection and appraisal survey of forest diseases, started last year, was intensified. We now have the organization to do a reasonably good job on pest surveys.

A significant organizational change in 1956 was the establishment of a division with responsibility for disease surveys and all aspects of tree disease research, including studies on blister-rust control. At present an 8-man research division has been organized.

Although we have had several retirements and transfers of key personnel during the past year we have been fortunate in obtaining excellent replacements. Several men have transferred here from other agencies or other units of the Forest Service. Others have been recruited to strengthen our staff. So, although our program and personnel have shifted somewhat, we have made substantial progress in pointing our program to meet future needs best. The most significant achievements of the past year are reported on the pages that follow.

FOREST ECONOMICS RESEARCH

LARGE OWNERSHIPS CONSOLIDATE HOLDINGS

Three developments have highlighted the forest economics situation in California during the past year: Consolidation of private forest land into larger ownerships; a slump in the lumber market in the late summer; and increasing interest in the manufacture of pulp and paper.

Ownership changes are occurring at a rapid pace as timber interests acquire additional land and stumpage to extend operations or to block in holdings for long-range development. Several consolidations that occurred during the year involved large tracts of timber and brought new ownerships into California

The Georgia-Pacific Corporation became a major timber operator and landowner in California with the purchase of the Hammond Lumber Company and the Feather River Pine Mills;

International Paper Company acquired the Long-Bell Lumber Company and extensive holdings in northern California; the Simpson Logging Company added over 60,000 acres to its holdings in northwestern California by the purchase of the M and M Woodworking Company, the Sage Land and Lumber Company, and the Northern Redwood Lumber Company.

These moves are bringing large, diversified manufacturing facilities--backed by ample raw material supplies--to California. The results should be a higher level of economic activity in the region's forest industries: more products to sell, more payrolls, and more income.

SLUMP IN LUMBER MARKET REDUCES PRODUCTION

The slump in the lumber market during the latter part of the year stemmed largely from the reduction of new housing starts throughout the nation. Construction species like Douglas-fir were hardest hit although other species were also affected. Through September, Douglas-fir production in the Pacific Coast states was down about 7 percent from last year. Prices of both lumber and plywood fell, and orders, production, and shipments slowed. A number of California mills reduced working hours and some closed for the winter ahead of normal schedule. Demand and prices leveled off at the end of the year, indicating improved markets in the spring.

PULP INDUSTRY PLANS NEW MILLS

One of the most encouraging aspects of the market outlook for timber has been the development of new pulp plants in the State. During the year construction was started on a plant at Red Bluff that will produce molded pulp products, and a new pulp and paper mill was announced for the Eureka area. The Forest Survey staff has been active in supplying information to guide new pulp developments, providing industry, state, and local organizations data on timber resources and on woods and mill residues.

LOG GRADING STUDIES TO AID MARKETING

Funds became available during the year for economic studies of timber-marketing problems. As a starting point, the Station is analyzing various log grading procedures in use in the state to determine their effectiveness in measuring timber quality. If this study works out, we hope to develop a standard grading system that will be acceptable to industry and the Forest Service. The latest

step in this work is a study of lumber recovery from white fir logs to determine the grades and dollar value of finished lumber obtained from different grades of logs.

SURVEY OF TIMBER CUT IS PLANNED

Marketing studies will also be aided by a survey of 1956 timber production in California planned this past year. The Station will carry out the work in 1957, after the plan receives clearance from the Bureau of the Budget and the Bureau of the Census. This survey is part of the Forest Survey program to obtain detailed information on timber production at least once in every 5 years. The last such survey was made for the year 1951.

We will ask operators of sawmills, veneer plants, pulpmills, and other primary timber-products plants in the state to report volume of production, species cut, and source of logs. This information, supplemented by data on wood residues from logging, will show the total volume of timber harvested or left on the ground during the year.

The mill questionnaires will be sent out early in 1957 and necessary field work will be done later in the year.

REINVENTORY OF TIMBER TO START IN 1957

We also laid plans to gather up-to-date information on changes in the timber resources available to support forest industries. This included selecting sampling methods, field procedures, and accuracy standards for the Forest Survey reinventory program. We have scheduled field work to start in the northern coastal counties in the summer of 1957.

In this area the first inventory is nearly 10 years old. Yet survey workers found that the original field plots will prove a big help in the reinventory. They went to 26 of these plots in Mendocino County to see if they could relocate plots and to learn how the timber had changed as a result of cutting, fire, growth, and other factors. Although nearly half of the plots had been cut over or burned since the original measurement in 1948, the survey crew found and remeasured all but one plot. Thus, we have assurance that the reinventory program can be strengthened by remeasuring some of the original plots while new field work is done.

SOIL-VEGETATION SURVEY COVERS SUBSTANTIAL ACREAGE

This year the cooperative soil-vegetation survey gathered more detailed information to guide future land management on nearly 700,000 acres in 3 counties. In Tehama County, field work is now nearly two-thirds done. The 1956 survey completed the area outside the national forests there, bringing the total to nearly a million acres, and work will start on the half-million acres of national-forest land early next year. Humboldt County, exclusive of national forest, is a little more than half completed. In Fresno County, survey crews continued work on the Sierra National Forest; the acreage completed includes Kaiser Basin, where logging is planned soon. Preliminary maps have been issued as a base for timber inventory and logging plans.

These investigations are under the general coordinating direction of the Station. The work in Tehama and Humboldt Counties is in cooperation with the California Division of Forestry and the University of California. The work in national forests within Fresno and Tehama Counties is in cooperation with the California Region of the Forest Service and the University of California.

The end products of the survey are maps of soils and vegetation; new maps were published in 1956 for a total area of 215,000 acres in Glenn, Tehama, Humboldt, and Fresno Counties. Maps of an additional 495,000 acres in these counties are being readied for publication. By early 1957 all of Glenn County will be complete.

By summer we expect to have ready a new colored map, "Upland Soils of Glenn County." This will be the third of its kind, following Mendocino and Lake Counties. It will show at one-half inch to the mile scale the different upland soils in areas of 40 acres and larger. These areas will be colored to show the vegetation these soils usually support, such as conifer timber, grass and oak, and chaparral.

LAKE COUNTY STATISTICS SHOW VALUE OF SURVEYS

That these surveys can guide land-use decisions is shown by Lake County statistics being cranked out of the Station machine-records unit. We have found about 180,000 acres of uncultivated soils there suitable for conifer timber production--nearly a fourth of the County. Although much of this area contains soils of good quality for timber growth, an appreciable acreage is now poorly stocked with commercial trees:

Timber site quality:	Acres	Acres with less than 20% conifer cover
High and very high	79,000	16,000
Medium	80,000	38,000
Low	21,000	5,000

Another 129,000 acres in Lake County has uncultivated soils that usually grow grass and oak trees. These soils are generally suitable for production of range forage but not for conifer timber. But woody vegetation, trees or shrubs, can reduce the yield of herbaceous forage. The survey has found that on a third of these soils, oaks and chaparral shrubs make up more than half of the total cover of vegetation. Only a fifth of the acreage can be called extremely open, growing almost entirely grass and other associated herbs. Operations to convert brush to grass will be most practical and likely to succeed on the lands in this category.

About 354,000 acres of soils are normally associated with chaparral and minor conifers. Generally not suitable for timber production, these soils are of low or very low suitability for range forage production under extensive management. Chaparral is dense or semidense on 86 percent of the acreage. The remainder is of varying degrees of openness, but mostly the shrubs are on their way back after fires. In general, these are problem soils for improving range forage production. They grow forage and shelter for a valuable wildlife resource, however, and they include some of the important sources of water in the County.

SPECIAL SOIL-VEGETATION STUDIES AID RESEARCH

Other research divisions at the Station have found they can strengthen their work through soil-vegetation studies. For watershed management research, the 2,500-acre Central Sierra Snow Laboratory was mapped at four times the usual intensity. This will provide a detailed picture of cover and ground conditions to guide snowpack research plans and to aid in interpreting results.

Also, two reservoir sites were mapped in the Kings River drainage of Fresno County at twice standard intensity. Watershed specialists will use this information in evaluating evaporation and transpiration of water from soils and plants.

Range research workers turned to a broad-scale reconnaissance of soil and vegetation for help in planning game-browse

studies. This reconnaissance was done on the east slopes of the Sierra Nevada and in the southern Cascade Range. It showed that differences in soils influence the distribution of bitterbrush, a valuable browse plant, and pointed up the importance of soils information when we interpret and extend the results of reseeding studies.

INTEREST EXPANDING IN SOIL-VEGETATION SURVEYS

As pressure builds up for more intensive use and management of western wild land, interest in soil-vegetation surveys is becoming more widespread. In Oregon, the Weyerhaeuser Timber Company recently surveyed about 60,000 acres in a pilot study area north of Klamath Falls. This survey followed procedures used in the California work. From Oregon State College, two members of the teaching and research staff visited the Station to find out about survey procedures. Arizona, vitally interested in the economic feasibility of increasing water yield from the Salt River Basin, recently received from staff and consultants of the Arizona Watershed Program this recommendation: "An intensive soil-vegetation survey of the entire watershed should run concurrently with the action program. Recent detailed surveys in California provide a pattern for similar surveys in Arizona."

Closer to home, the Agricultural Extension Service in Humboldt County assigned a specialist to work full time with ranchers in using soil-vegetation survey information. Local agencies sponsored field demonstrations of survey work for ranchers and conservation students. In Sonoma County, the Board of Supervisors has requested a survey be made soon.

FOREST MANAGEMENT RESEARCH

COOPERATIVE RESEARCH LAUNCHED IN REDWOOD AND DOUGLAS-FIR

One of California's most richly endowed timber regions will receive sustained, systematic research for the first time as a result of work the Station is starting in northwestern California. There the Simpson Redwood Company and the Station have launched a cooperative project seeking answers to forest management and utilization problems in redwood and Douglas-fir timber.

Site of the new project will be timberland on High Prairie Creek in Del Norte County. The area includes about 900 acres in the Station's Yurok Redwood Experimental Forest and an adjoining 1,100 acres owned by the Simpson Redwood Company. The company will log timber on both tracts by special methods set up as part of the research plan. It will also contribute to the cost of experimental work and will take an active part in planning and completing the work. The company will pay the appraised valuation of publicly owned timber removed during the experimental harvesting.

Federal, State, and private agencies all have conducted some research in this region. They have worked out much helpful information, but most of their studies were limited in scope or were short-time projects. As we reported last year, forest managers still lack a good deal of information. The Company and the Station hope to provide many of the technical tools needed for sustained yield management of the timber crop.

EXPERIMENTAL CUTTING TO START IN RED FIR FOREST TYPE

In northeastern California, we got set for a second new timber cutting experiment--this one in the red fir type. Extensive timber harvesting began only recently in this type, but the rate of logging is increasing rapidly. Both forest managers and silvicultural researchers are learning for the first time what the important problems are in managing red fir forests. Hence, compelling reasons existed for starting a program of experimental cutting.

In 1956 a working plan was prepared for experimental harvesting and regeneration operations at Swain Mountain Experimental Forest. The forest, situated 11 miles north of Westwood, contains heavily stocked old-growth fir stands.

Red fir and white fir timber on Swain Mountain Experimental Forest. Numbered trees will be harvested in 1957.

In general terms, the plan provides for harvesting and regenerating by the most promising method that we knew how to devise. Costs of the operations will be collected and results will be measured.

The method that has been selected is a form of even-aged management. The major kind of harvest will be clear cutting in strips about 300 feet wide, beginning at the northeast corner of each compartment. The strip will be oriented in a southeast-northwest direction at right angles to the prevailing wind. This will protect the windward edge of uncut timber, and help scatter seed into the clearings. Successive cuts in each compartment will be made at 10-year intervals progressing in a southwest direction.

That is the general pattern, but many variations will occur. Differences in age of the trees, changes in topography, location of roads, and variations introduced for experimental

purposes will prevent the development of a completely systematic pattern. Salvage and sanitation cutting will be limited to very light cutting in places where skidding distances are short and where final cutting will occur in less than 30 years. This restriction of partial cutting is being made in order to lessen decay losses that result from partial cutting. About 4 million board-feet of timber will be harvested each year.

NEW BASIC STUDIES SEEK CLUES TO PLANTING SUCCESS

A third major change in forest management research at the Station is the start of fundamental studies in the field of reforestation. A specialist in plant physiology has been assigned to this new project. Located at the California Institute of Technology in Pasadena, he will have available the excellent laboratory and plant growing facilities of that institution. His studies will be directed toward bettering the survival of planted tree seeds and seedlings. They will include determination of moisture, temperature, nutrient, and light requirements for germination and growth.

APRIL-LIFTED TREES PRODUCE MORE NEW ROOTS

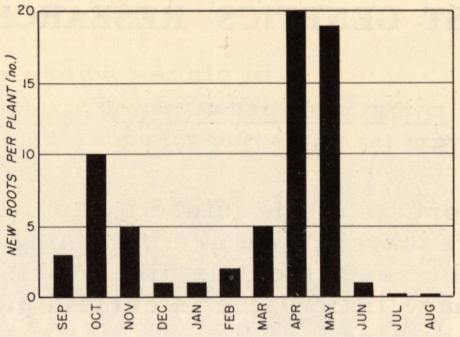
How laboratory research can pay off in planting studies was illustrated by a preliminary study of root initiation on ponderosa pine transplants in cooperation with the School of Forestry, University of California. We found that April-lifted trees produce the most new roots within 1 month. This is not a brand-new discovery. Others have observed better root growth in the spring. The news is that we know when the peak or peaks in root activity occur in California and how close these peaks coincide with the normal planting seasons.

The transplants were taken from the Mt. Shasta Nursery in the second week of each month, packed in moist sawdust and vermiculite, and shipped to Berkeley. Upon arrival they were planted in 5-gallon crocks filled with sand or "sponge rok" and watered twice a day with a balanced nutrient solution. All excess nutrient solution was drained out of the crocks after each watering. The root temperature was held at 68°F. (20°C.). The trees were removed and the roots counted and measured 30 days after each planting.

Two flushes of new root growth were noted. The lesser flush started in September and ended in November. This period does not always coincide with the fall planting season in California. Much depends on the time and amount of early fall

rains. For many parts of the Sierra, new root growth would be on the decline long before the rains wet the soils deep enough for planting. At best, the fall planting season is short.

The greater flush of new roots started in March and ended in May. Here, root development is at its peak when planting conditions are most favorable.



Ponderosa pines produced more new roots when dug from nursery beds in April and May.

COSTS DETERMINED FOR SEEDBED PREPARATION

In managed forests, one of the important objectives is to start a new timber crop immediately on all areas that are not stocked with young trees when the old growth is harvested. Therefore the first step after logging usually is to make sure the ground conditions will favor establishment of seedlings. In several California forest types this means a mineral soil seedbed free of competing vegetation. The same requirements prevail whether the tract is regenerated by natural seedfall or by artificially planting seed or nursery stock.

Five years of experience in seedbed preparation at the Blacks Mountain Experimental Forest have given us some cost records of interest to forest managers.

The equipment used most of the time has been crawler tractors with solid-edge angledozer blades. Costs varied considerably from year to year owing to differences in machines, operator efficiency, and intensity of work. One year the cost was only $7.91 per acre of regeneration area, but the work later was concluded to be seriously deficient in thoroughness. For the 4 years when clearing was satisfactory the average cost, including overhead charges, was $46.00 per acre. Since practically all logging slash and other fuels were piled and burned, a considerable part of this cost should be regarded as of value for fire protection. In view of the fundamental importance of re-establishing a forest, the expense is not considered prohibitive. However, we will seek ways to reduce it. The methods and analysis of the costs have appeared in more detail in an article in the Journal of Forestry.

FOREST GENETICS RESEARCH

SOME PINE HYBRIDS SHOW PROMISE IN FIELD TESTS

One way to meet the increasing need for forest products is to produce improved trees for the forests of the future by applying the results of forest genetics research. We are beginning to learn what can be expected of the results of our pine hybridization research. Some evidently have little value in certain places; others show a great deal of promise.

Results of our crossing experiments must undergo rigorous tests before the crosses can be recommended for wholesale reforestation. The seeds produced by artificial pollination are first tested at the Institute of Forest Genetics, near Placerville, for hybridity and early performance. Then, to see how the hybrids will do in the environment of their parents, we send seed to cooperators in other regions for planting tests. This procedure is yielding valuable information on the potentialities of the hybrids.

The Illinois Agricultural Experiment Station, for example, has reported that our shortleaf-pitch pine cross proved "weak and worthless" in southern Illinois. But the pitch-loblolly pine hybrid, proved "vigorous, a good form, and hardier than either shortleaf or loblolly pine."

The Texas Forest Service has reported performance of 13 of our hybrids in Texas and Louisiana. Four were outright failures. The other nine showed good growth; though not likely to replace any of the southern pines on a large scale, some may be useful in certain places.

Federal and industrial foresters in Louisiana have reported that the cross between shortleaf and loblolly pine has proved resistant to fusiform rust--a serious and widespread disease of loblolly pine in the south.

The hybrid of pitch pine x loblolly pine is in production by tree breeders in South Korea, where it evidently shows great economic potentialities. Seed orchards of the parental species are now being established along the southern coast. Hybrids will be mass-produced through hand pollination until the trees come into flowering. Then, since blooming of both parents overlaps, wind pollination will be relied on to carry loblolly pollen to the pitch pine conelets. Catkins will be removed from the pitch pine.

In this South Korea seed orchard, Seoul National University's institute of forest genetics is producing for reforestation a pine hybrid first produced experimentally in California. In view here are some of the 30,000 bags used to protect hand-pollinated conelets in 1956.

At Placerville, we started a new 5-year series of experimental crossings. This series has two main purposes. It will test the revised classification of the relationships among pines developed at the Institute of Forest Genetics as a result of past crossings, and it will explore systematically the most promising crosses suggested by this classification. As a part of this program, we repeated old crosses or attempted new ones among these pines:

Seed parents	Pollen parents
Himalayan	Armand, Mexican white, and sugar
Limber	Armand, Mexican white, sugar, and Himalayan
Shortleaf	Longleaf
Loblolly	Longleaf
Pitch	Slash and Monterey
Digger	Coulter and Torrey
Maritime	Corsican and Scotch
Scotch	French mountain, Mugho, Swiss, Austrian, and Corsican
Japanese black	Scotch

PINE RACES MAY DEFINE "LOCAL SEED SOURCE"

Experience and research have led to the conclusion that "local seed source is best." To the practicing forester, this means that seed for reforestation should be collected near the site to be planted. To the tree-breeder, it means two things. One is that he should use "local" trees as parents in producing improved trees through selection; the other, that he should give careful attention to source of parents in producing improved trees for specific localities through hybridization. In short, forest-tree improvement should be based on knowledge of racial variation in the parental species. The evidence accumulated to date shows that most species consist of races adapted to different localities. A key problem, then, is to define what is meant by local.

For each species, or for each segment of the range of a species, the word might have a different meaning. In seeking to define local source, we might start with the individual tree and work out through its neighbors in the forest to delimit a local source. Conversely, we might start with the entire species and work down to the individual tree. We have chosen this latter approach for our study of geographic variation in ponderosa pine.

Those trees which look alike may act alike; therefore, one clue to the limits of a local source is a simularity in form. Many characteristics, of course, are expressions of interaction between the genetic makeup of the tree and the modifying influence of the environment. Hence, similarities in form may indicate a like genetic structure or environment. Specimens representing the entire range of ponderosa pine were studied intensively

during the past year. Many characters show a distinct pattern of geographic variation. Among them are length of the needle-fascicle sheath, and size and shape of the cones, seeds, and seed wings.

Another means of definition is the similarity or dissimilarity in growth response of seedlings from different areas. To appraise these qualities, we started studies of ecological adaptation with seeds representing many different sources of ponderosa pine. The rate at which seeds germinate was determined in incubators held at 8, 16, 24, 30 and 36°C. The first of a series of three examinations of geographic differences in seedling development was completed. Further studies of development of seedlings from different sources were made under controlled conditions at the Earhart Laboratory, California Institute of Technology. There the length of day and the day and night temperatures can be varies independently. The effects of variation in these environmental factors on the growth and dormancy of seedlings has been measured during two growth flushes.

The measurement phase of this study is just about complete. Analysis of the results will proceed during the ensuing year. Business-machine procedures will be used throughout this work.

BASIC RESEARCH SEEKS SECRETS OF FLOWERING

Tree breeders and forest managers are often thwarted by erratic or inadequate seed crops on the trees they would like to reproduce. Both would like to know how to bring about reproductive maturity in an individual tree, or how to insure early, abundant, and regular fruiting. We are beginning to piece together the information they need through fundamental studies of the flowering process in pines, which we are conducting in cooperation with Resources for the Future.

To do the job, we have reorganized and equipped the laboratory in Berkeley for study of the anatomy, biochemistry, and physiology of flowering.

One poorly understood process is the germination and growth of pine pollen. To study its development, though, we first had to find a material in which it could be grown. The medium had to be toxic to contaminating fungi but harmless

Chemical analyses are part of the fundamental studies seeking a better understanding of the flowering process in pines.

to pollen. Mysteclin, a commercial antibiotic mixture, proved most satisfactory. We found, too, that contrary to common belief sucrose does not stimulate germination of pine pollen and has but a slight effect on growth of the pollen tube. On the other hand, indole-acetic acid does stimulate germination, and temperature and acidity of the medium also influence it. Another phase of the pollen study started during the year is a chemical analysis of pollen pigments to learn if these substances affect its development.

To learn what triggers flower formation in pine shoots, we need to know just when flower buds are formed. So we collected pine branches at 2-week intervals from February to September and once each month thereafter. The branches were stored in preservative, and anatomical studies will reveal the timing of flower formation. Meanwhile we worked out methods of chemical analysis that will show what substances were present in flowering and non-flowering shoots at different times.

In another study, vegetative growth of pines proved sensitive to length of daylight, but flowering was not affected by changing the photoperiod. Thus, we know that capacity to produce flowers is not hindered when southern species are moved to the north or when northern species are moved south. Experiments also were started to determine the effects of continuous light on seedlings and the effects of gibberellic acid--a newly discovered hormone--on growth and flowering in pines.

In work on vegetative propagation of pines we found that sugar pine, which is extremely difficult to root from cuttings, can be rooted through air-layering. This technique should help in reproducing the species for studies of resistance to white pine blister rust.

HIGH SURVIVAL OBTAINED IN FIELD TESTS OF HYBRIDS

That forest tree planting in California can be highly successful was shown by a field test of hybrids set out in the spring. About 10,000 pine hybrids and an equal number of non-hybrids were interplanted by personnel of the Eldorado National Forest on well-prepared sites at an elevation of 4,600 feet near Pilot Creek. Eight different hybrids are represented in these plantings.

All the trees were 1-year-old seedlings grown at the Institute of Forest Genetics. Spacing in the nursery beds was about 16 seedlings per square foot. Consequently they had well developed roots. They were lifted from the nursery beds just before planting time, carefully handled to keep them moist, and planted by standard methods. Percent survival at the end of the first growing season was:

Jeffrey x Coulter hybrid	97
Jeffrey x (Jeffrey x Coulter) hybrid	94
Jeffrey x (Jeffrey x Coulter) x ponderosa hybrid	94
Jeffrey x ponderosa (natural hybrid)	100
Ponderosa x ponderosa (Arizona variety) hybrid	85
Ponderosa x Apache hybrid	90
(Ponderosa x Apache) x Montezuma hybrid	92
Ponderosa x Montezuma hybrid	87
Jeffrey pine	95
Ponderosa pine	91

Good site prepatation, vigorous stock, and careful planting were the main reasons for this record.

NEW ARBORETUM SITE ACQUIRED

The most complete collection of pines in the world is growing in the Eddy arboretum at the Institute of Forest Genetics. But some pines do poorly there. The comparatively low elevation is not well suited to the development of some white pines and certain species normally occupying moist or cool climates. This year a new arboretum site was acquired on the Georgetown District of the Eldorado National Forest. This higher-elevation site, which is only a few miles from the Institute, will be developed primarily for the species which do not do well at Placerville. Some of the area also will be reserved for research tests of pedigreed progenies.

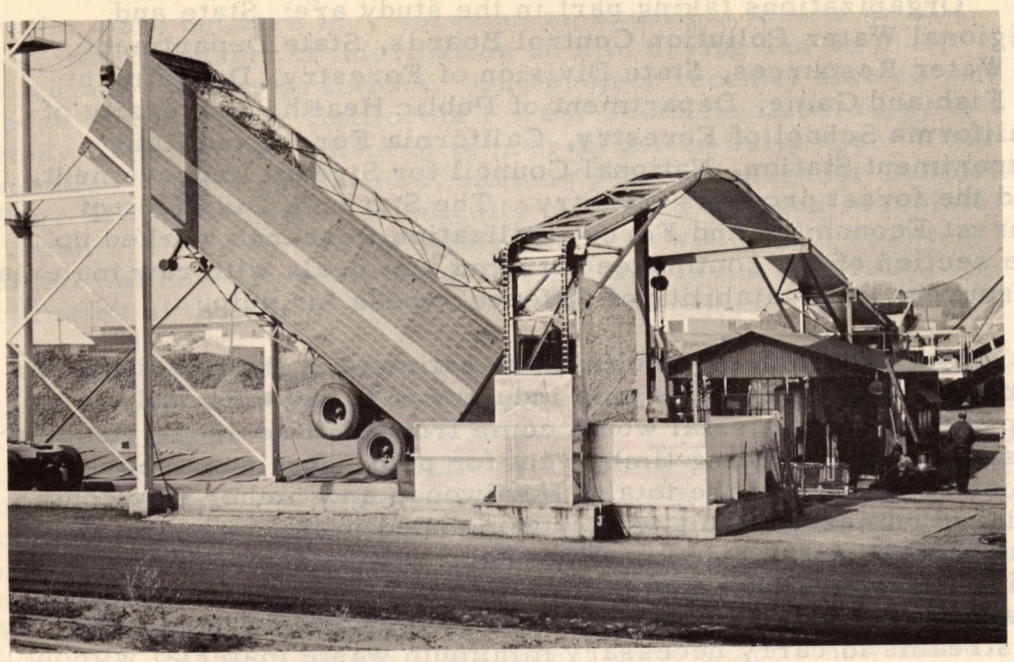
FOREST PRODUCTS UTILIZATION RESEARCH

INDUSTRY TRENDS OPEN DOOR TO IMPROVED UTILIZATION

A heartening aspect of changes in California forest industries is the prospect of better wood use in the forests and mills. One organization taking part in the consolidation of ownerships is already making plans for a major pulp and paper mill in the Eureka area. Others, showing definite interest in some form of pulp operation, are analyzing the amount and sources of raw material and studying different pulp- or board-making processes. As their plans come into effect, they should open new markets for logging and mill residues. They should also help bring into use low-value trees and species now unmerchantable.

The Station has furnished information to several companies. Some are looking to greater use of the wood reaching their established sawmills. Others are out-of-state operators interested in the possiblities of setting up fiber-using plants here. The principal reason for accelerated interest in pulping seems to be an increasing awareness of the suitability and value of plant residues as raw material. Another reason may be the search for new sources for raw material by the rapidly expanding pulp and paper industry of the country. We have received inquiries from companies operating in several other regions.

For several years chips made from slabs and edgings have supplied a large and increasing part of the wood for the two existing plants in the state. At first sawmills picked from the waste conveyor only slabs and edgings that had little or no



Wood chips from sawmills, here being dumped from a truck trailer for stockpiling, are making up an increasing amount of the raw material for California pulp mills.

bark. In the past few years, however, several mills have installed hydraulic and mechanical debarkers. Now a larger volume of material can be chipped, and the essentially bark-free product has a higher use value for pulping.

PULPING POSSIBILITIES STUDIED BY STATE, FEDERAL AGENCIES

The wide interest in pulping possibilities in California has prompted the State Water Pollution Control Board to organize a committee of interested agencies to help summarize pulping potentialities and their relation to water control problems. The report is to include information on wood fiber resources, pulping qualities of local woods, pulp and paper mill potentialities, water requirements, water supply, mill wastes, and the capacity of streams to handle pulping residues. This summary will be useful to many agencies directly or indirectly concerned with problems incident to the operation of pulp and paper mills. Also, it will give interested industrial organizations a well-rounded analysis of local conditions when considering the establishment of new plants.

Organizations taking part in the study are: State and Regional Water Pollution Control Boards, State Department of Water Resources, State Division of Forestry, Department of Fish and Game, Department of Public Health, University of California School of Forestry, California Forest and Range Experiment Station, National Council for Stream Improvement, and the forest products industry. The Station's Divisions of Forest Economics and Forest Utilization Research worked up the section of the committee's report that deals with raw material resources and suitability of different woods for pulp.

The committees' preliminary estimate is that the state has enough wood to support a pulp industry of 6,000 tons daily capacity. The material would come from mill residues, logging residues, and standing timber cut for pulp. Residues represent about 70 percent of the total. Hardwoods and timber now considered unmerchantable were not included in the estimate; they could increase the supply. When the study is complete, early in 1957, we should have sound information on the amount of water available for industrial use such as pulping and on the ability of streams to carry necessary minimum waste material without impairing other beneficial uses.

Research at the U. S. Forest Products Laboratory is turning up new raw material sources. The Laboratory found that redwood can be pulped and bleached readily. Extractive content is high, so pulp yields are somewhat lower from redwood than from other conifers. The difference is relatively small, however, when pulping young-growth redwood. The Laboratory has also found that tanoak pulps readily, giving good yields and properties like those of other hardwood sulfate pulps.

LUMBER PRODUCERS CONTINUE INTEREST IN WOOD SEASONING

Another sign that forest products industries are keeping abreast of market trends is the continued high interest in better lumber drying. This interest was highlighted in 1956 by a demonstration course in kiln drying held at the Richmond Forest Products Laboratory of the University of California, and by the meeting of the combined western dry kiln clubs in Berkeley. This Station and the U. S. Forest Products Laboratory cooperated in putting on the kiln course. Although a limit of 30 enrollees was planned, 33 were finally accepted and several applications were refused. Experience has shown that adequate personal attention and consultation is impracticable if too large a class is enrolled. The meeting of kiln clubs was attended by about 300 operators from all the western states.

We are working closely with the four kiln clubs organized in the state because they serve as an excellent means for disseminating technical information on kiln drying and do much to advance drying practices. One project recently started with these clubs and the California Forest Products Laboratory is a study of moisture content of lumber in use in buildings. Wood samples have been placed at various points throughout California. They will be weighed periodically to record changes in moisture content. From this record manufactures will gain a better picture of how dry wood should be for use in the different climates of the state.

HARDWOODS OFFER ADDITIONAL RESOURCES

Use of local hardwoods is still largely in the "under study" stage. Charcoal plants make up one active consumer, and it is especially interesting that practically all of the wood used is oak coming from what are considered non-commercial forest lands or woodland types. At least 12 or 15 new installations have been built since the war. Most operators use live oak; several in the Sierra Nevada foothills use blue oak. We have worked with some operators on kiln design, operating practice, and briquetting. We do not know exactly how many plants are operating, but a survey is to be made in 1957 by the Division of Forest Economics. It should show the number of operators, wood consumed, charcoal produced, and other information.

As yet no sawmill has started regular production of hardwood lumber although larger mills are actively working with these woods. California black oak and chinkapin have been marketed in a Los Angeles trial, apparently with satisfactory results. There is a renewed interest in production of veneer from hardwoods and the Station is now working with the Forest Products Laboratory on some additional experimental veneer slicing of at least two of the coast hardwoods.

FOREST FIRE RESEARCH

PREVENTION RESEARCH SHOWS PROMISE IN NEW APPROACH

Everyone agrees that the easiest fire to control is the one that doesn't start. Yet research on ways to prevent fires is still in its infancy--pretty much part time and widely scattered. In the West, about two-thirds of this effort is going into prevention of lightning fires. This is an important job, but in much of the country man-caused fires are bigger headaches. To reduce them, recent studies at the Station suggest, the most profitable research may be through controlled experiments and opinion-survey techniques.

A good many studies have correlated fire starts with weather, fuel conditions, persons using the forest, and level of prevention effort. Research workers soon learned that an increase in fires is not directly proportional to increased forest use. The mere fact that more people are in the woods seems to make each person a little more careful with fire, whether or not prevention measures are stepped up. Researchers have learned that permanent residents and outside visitors pose separate prevention problems, and must be considered separately when determining fire risk. But they also found that the correlation type of analysis has limitations as a prevention-research tool. Many variables must be considered, and the type and level of forest use change rapidly. Statistical analyses provide few guides for prevention action. We have concluded, therefore, that the most useful results can be obtained from controlled experiments to see how people respond to fire-prevention programs and from direct measurements of their attitudes and habits.

We have contracted with the School of Public Administration, University of Southern California to start putting this kind of information together. This group will work along two broad lines. It will devise instruments and techniques to measure awareness of prevention effort in such forest users as hunters and fishermen, and it will work out experimental designs for large-scale surveys of human reaction to prevention programs. Three studies are already started: development of a test of fire law knowledge, similar to the state driver's examination; an analysis of fire-prevention material in public school textbooks; and an evaluation of fire-prevention material in leading outdoor sports magazines.

STUDIES YIELD SOME GUIDES TO PREVENTION ACTIVITIES

Some help in making fire-prevention decisions has come from three projects under way at the Station. One question prevention officers often ask is "How reliable are statistics on the cause of fires?" Some research workers have found individual fire reports grossly unreliable as to fire causes. A special study by the Station, however, indicates that this may not be true in California.

We are going through all 1955 and 1956 fire reports from the State Division of Forestry and three national forests, checking the reasons why each reporter chose a particular cause. Preliminary study of 1955 national-forest reports shows that on the whole the data were reliable. There were two exceptions. For fires called smoker-caused and for distinctions between local or outside residents, the evidence was often weak.

Another perplexing question is "How can we measure the effectiveness of prevention activities?" The answer ought to be tied into the over-all objective of fire control: to hold fire damage below the level at which it would seriously restrict the yields from forest land. Thus, fire suppression workers measure their success against a goal set up in terms of maximum burned acreage. A similar goal, related to fire damage, was desired for fire prevention. We know that the probable final size of any fire is related to the fire danger rating at the time of the fire. Therefore the rating at the time a fire starts can be used as a measure of the damage potential of that fire. Although we cannot apply this yardstick to fires which did not start, we can compare fires that start against their potential, and thus derive a measure of prevention success. Such a system, designed to intensify prevention effort when fire danger is high, has been devised for test on all national forests in California.

For the question "How can fire hazard on logged areas be reduced economically?" the portable chipper promises an answer. A study of the economics and performance of chippers in California is under way in cooperation with the University of California. Results so far show that costs of shipping brush ranged from $9.25 to $13.25 per hour. Costs for chipping timber slash ranged from $20.00 to $22.25 per hour. Chipper users reported advantages over other hazard-reduction methods. They stopped damage to reproduction caused by burning slash, and they realized a 6 to 1 saving in shipping space where brush was removed by truck.

LOCAL FIRE WEATHER NEEDS MORE STUDY

The index of fire weather severity devised in 1955 was used by California national forests during 1956 to supplement fire danger ratings. Low severity indexes in northern and central California showed the fire weather to be "easy" this year. The fire record for these areas reflected this favorable weather. Area burned by man-caused fires was less than 10 percent of the previous 5-year average. Number of man-caused fires was also well below normal.

In southern California the picture was very different. Severity indexes were extreme in many places, and the potential for large fires was great in most of southern California by the first of October. These conditions were climaxed in November by prolonged Santa Ana winds. Fuel moisture, already low from extended drought, dropped to a minimum. Moisture content of green chamise and sage twigs and foliage was close to 50 percent, about the lowest ever recorded for these species. Moisture in dead fuels was 3 to 4 percent. Two fires in November burned nearly 60,000 acres and caused the loss of 11 lives, bearing out the significance of the servity index in evaluating seasonal fire danger.

To capitalize on this new tool, however, fire fighters need better weather information to guide their predictions of fire behavior. With the cooperation of the California Division of Forestry and the U. S. Weather Bureau, we are working on three of the most urgent needs: an improved system of rating fire danger, better measurements of fire weather, and better knowledge of fireclimate.

A pilot model of California's new fire danger rating system was tested by the Division of Forestry and the U. S. Forest Service in northern California during the 1956 season. Performance data are still being analyzed. The new system will be put into more extensive use in 1957.

The Station completed inspection of fire weather stations on national forests, started in 1955. In the 2 fire seasons, 172 established stations were inspected, 22 new stations added, and 15 stations closed. Inspectors found that most stations could improve their measurements of fuel moisture and wind flow.

Two fireclimate surveys were started in 1956. Both collected information on local weather important to fire control so that fire research can...

...Describe local weather patterns in major drainages, especially wind patterns, that will accompany a particular weather situation;
...Determine the number and location of permanent climatic stations necessary to detect changes in the daily and seasonal fireclimate which affect fire behavior and fire fighting tactics;
...Determine effects of topography and vegetation on local fireclimate patterns.

FIRECLIMATE SURVEYS HELP PREDICT FIRE BEHAVIOR

The largest fireclimate study was in the Arroyo Seco drainage on the Angeles National Forest. From July through mid-October, we recorded wind speed and direction at 10 stations, and temperature and humidity at 6 stations. Data are now being tabulated and analyzed to correlate wind patterns in the canyon with the general weather pattern and with wind observations from surrounding lookouts. Observations show that eddies in draws and canyons cause extremely complex wind patterns. We are just beginning to recognize the importance of eddies in predicting fire behavior in rugged topography.

A study of how movement of marine air affects fireclimate in the Arroyo Seco was started through a cooperative agreement with the Geography Department of the University of California. Some interesting items have already come to light, such as the presence of fresh marine air in the canyon when a large surface pressure difference exists between the coast and inland, and the presence of double temperature inversions. This study is expected to provide much needed quantitative information about this important factor in fireclimate all along the California coast.

A second wind study was made for the Iron Mountain control burn on the Lassen National Forest. The proposed burn area, of about 1,000 acres, was surveyed by a small task force with portable instruments for 3 days before the fire. The team established air-flow patterns for the existing general weather conditions, and gave the fire boss an accurate and detailed forecast of probable wind direction and velocity for the day of the burn.

Wind measurements during the fire showed that the fire switched the wind through a saddle one-fourth mile away--from westerly at 11 m.p.h. to easterly at 7 m.p.h. These observations suggest that entrainment of air into the side of the convection column may be greater than the inflow into the base of the fire. There is a critical need for wind studies around fires to determine major effects of the fire on local winds.

We believe a task-force survey can be an efficient and rapid means of obtaining weather information about specific mountain areas. It can also be used effectively to study effects of topography on fireclimate. More surveys of this type are planned for 1957.

NEW TOOLS FOR FIRE FIGHTING USE AIRCRAFT, CHEMICALS

New this year is Helitack--a research and equipment-development program aimed at making a better fire tool of the helicopter. The Station's fire research team is coordinating this program for the U. S. Forest Service and the State Division of Forestry. The Forest Service's Equipment Development Center at Arcadia designed and arranged production of a hose tray which allows a helicopter in flight to lay fire hose over rough terrain. This device can lead to stronger and faster attacks on fires. In one test 8 men on the ground needed 30 minutes to lay 1,500 feet of linen hose up a 70 percent brush-covered slope. The helicopter did the identical job in 53 seconds. Other Helitack work includes the development of helicopter accessories for bulk water drop and portable tankers, the study of aircraft management on going fires, and, in cooperation with Utah State Agricultural College, development of operational guides for specially trained crewmen.

When the Mendocino National Forest activated 7 crop-duster planes as air tankers, practical air attack on fires became possible. These planes fought 25 fires this year, droping 150,000 gallons of water and chemical on them.

Air tankers assured control on 16 of these fires; on 4 fires they were a help; on 4 others they were of no benefit; and on 1 fire they caused loss of line by extinguishing a planned backfire. Besides evaluating the air tanker results for 1956, the Division of Forest Fire Research conducted an intensive series of calibration tests for chemical attack from the air and an operations conference of fliers and users.

Helicopter equipped with new hose tray demonstrates how it can speed hose-laying job for fire fighters on the Klamath National Forest in northern California.

Sodium-calcium borate continued to develop as a major advance in forest fire fighting. This chemical retardant was used for direct attack on more than 10,000 feet of line on 14 fires and as pretreatment for backfiring on some 12,000 feet. Also, 65,000 gallons were dropped on 14 fires from air tankers. The mixture of water and chemical shows significant advantages over water; it reduces the number of reignitions, and it retains a retardant effect after the water has evaporated. The success of these trials has stimulated research and field men to develop new fire fighting methods with chemicals.

FIRE PHYSICS STUDIES AID DEFENSE PROGRAM

All field and laboratory work for the Department of Defense was completed this year. Seven study reports were completed and summary application reports in preparation will be finished by July 1, 1957 when the program is terminated.

A study of the influence of mass-fire situations on radiological defense planning was begun this year in cooperation with "Project Civil" of the Department of Engineering, University of California. A limited field experiment and an analytical study indicate that fires, particularly large fires, may change fallout patterns around nuclear detonations. Further work is now being planned.

The Station's fire physics program concentrated on studies of how fire size affects model fires. Test fires burning liquid hydrocarbon fuels showed that rate of combustion increases only slightly with fire diameter for laboratory-scale fires. Although we cannot yet predict forest fire behavior from results of laboratory fires, this information is one step toward that goal.

Fire-retardant mixture, sodium calcium borate, dropped from air tankers stopped this critical point of the 45,000-acre Inaja fire on Cleveland National Forest in southern California.

MOTION PICTURES PROVIDE NEW TRAINING AIDS

The Station produced four sound and color motion pictures in 1956. "Training in the use of water on forest fire," shows how a 5-man training team can demonstrate efficient and conservative use of water. Used by field men this spring, the film cut the time for learning the demonstrations by 2 days.

"How to make fire weather observations" shows how to make observations using the standard instruments found in a fire weather enclosure, points out why accurate and daily weather measurements are important, and emphasizes the relation between fire weather and fire danger.

"Helicopter hose lay" shows how to lay fire hose by helicopter over rough terrain and low vegetation. It demonstrates how to pack hose in the tray, how to attach the tray and adapter assembly to the aircraft, and safety precautions in its use on going fires.

An orientation-type teaching film, "Brush control with chemicals on forest roads and trails," shows engineers and others responsible for maintenance: what to do before beginning a chemical spray program, what equipment to use on both roads and trails, and how and when to do follow-up work.

FOREST INSECT RESEARCH

FOREST INSECT SURVEYS SHOW CONTINUED LOSSES

Surveys conducted by the Station show that destructive insects continue to compete successfully with other users for a share of California's forest resources. Some of our most serious insect pests suffered sharp reverses this year; others increased their depredations. The net result is that the overall level of damage for 1956 is not much lower than it has been for the past 4 years.

Even so, the insect-loss picture is much more favorable than was expected, for at the beginning of the year potentials existed for much greater damage than actually developed. Some infestations declined because of controls imposed by nature. Others declined because of unremitting efforts by man to suppress them. Some potentially destructive pests were held in check because management practices developed by the Station and now widely used make it increasingly difficult for epidemics to develop.

A sharp downward trend in damage was the rule for these insects in 1956: Douglas-fir beetle, Douglas-fir tussock moth, pine engravers, and cone and seed insects. Natural factors are credited with the decline of the Douglas-fir beetle and cone and seed insects. Sprays controlled the Douglas-fir tussock moth, while management practices and suppressive measures did much to check pine engravers.

Insects that continued to cause moderate damage were: Jeffrey pine beetle, western pine beetle, fir engraver, pine reproduction weevil, and California flatheaded borer. Most caused normal amounts of loss throughout their range. Two were locally destructive. In southern California and in the westside Sierra foothills, the western pine beetle continued to kill great numbers of ponderosa pine. And in Siskiyou County, an infestation of the pine reproduction weevil broke out and destroyed part of a young pine planting in a brushfield.

Two insect pests of long standing continued to ravage stands prized for their recreational values in the high Sierra. The lodgepole needle miner stripped most of the foliage from lodgepole pine on a 50,000-acre area in Yosemite National Park. Trees weakened by the needle miner are favored breeding sites for the mountain pine beetle, and by the end of the year a good-sized beetle infestation was gaining momentum in the heart of of the defoliated area despite efforts to hold it in check. Malathion sprays applied with a mistblower were used with some success against the needle miner, but this equipment could spray only trees bordering roadsides and campgrounds.

The mountain pine beetle was also on the increase in other parts of the state, notably in lodgepole pine in the South Warner Mountains of Modoc County, and in ponderosa pine near Lake Tahoe. In addition, this beetle caused a moderate amount of damage to sugar pine in the central and southern Sierra.

Contrary to our expectations, serious insect outbreaks did not develop in the wake of the 1955 forest fires. The chief reason is the prompt salvage of most fire-damaged timber. There is some chance that insect damage around these burns will increase in the spring of 1957, but salvage logging has considerably reduced the hazard.

The Station has redoubled its efforts to improve insect surveys, for effective detection and appraisal are the key to insect control. We have received valuable assistance from many

field-going foresters, particularly those in the State Division of Forestry. The Station investigated more than 130 reports of damage. In cooperation with federal and state foresters, our entomologists made appraisals of nearly one-third of the infestations reported. Critical infestation areas were examined from the air in the spring and in the fall. In addition, we advised land-managing agencies and private owners on the entomological aspects of the insect control programs.

DDT AERIAL SPRAYS CONTROL TUSSOCK MOTH

Chemical sprays controlled the Douglas-fir tussock moth during the year in California's first successful large-scale aerial operations against a forest insect. National-forest officers conducted the operations, with the help of the State Division of Forestry and private land owners. Station entomologists provided the technical guidance necessary to the success of this kind of job.

The Douglas-fir tussock moth is an insect that causes damage by devouring the foliage of its hosts: white fir and Douglas-fir. Trees completely stripped of their needles by the caterpillars die; those partly defoliated suffer growth losses and may succumb to later attacks by bark beetles. The moth is native to California and many other parts of the West. Though abundant in this state several times in the past 50 years, it had not been considered economically important because of the low value previously placed on fir.

Object of the 1956 control campaign was an infestation that broke out in Tuolumne County in 1955 and damaged fir timber over a considerable area. Some sapling and pole-size trees were completely stripped of their needles; many larger trees were partly defoliated, particularly in the upper part of the crown. Station survey crews found 7 separate centers of damage, ranging in size from 350 to 5,900 acres. The aggregate area in these centers was 9,560 acres, about 80 percent of which was in the Stanislaus National Forest.

Early in 1956 we collected moth eggs from several centers; advance rearings showed that prospects were good for a heavy caterpillar population this year, and land-managing agencies decided to control the outbreak. They hired a commercial spraying concern to treat the infested acres between July 31 and August 2. Its crews sprayed DDT in oil solution, at the rate of 1 pound per gallon per acre, from a converted B-18 bomber.

White fir in this stand was severely defoliated by caterpillars of the Douglas-fir tussock moth (inset); further damage was prevented by spraying the outbreak area with DDT.

Station entomologists checked the density of the spray pattern and size of droplets; they determined the adequacy of spray applications on the infested areas by means of oil-sensitive cards placed at strategic points in each area; and they surveyed pretreatment and posttreatment damage to determine the degree of control. They also checked the kill of tussock moth caterpillars by counting the dead that fell into cloth trays placed beneath infested trees. Without exception, they found that the aim of the control project was achieved. The threat of further damage in the infested areas was forestalled.

ENVIRONMENTAL FACTORS AFFECT BEETLE DAMAGE

Foresters and entomologists have known for a long time that beetle-caused mortality in ponderosa pine fluctuates widely from year to year. But they have not known just why these fluctuations occur. Station entomologists now have pinned down certain environmental

conditions as primary factors. Their findings give land managers some new weapons to combat outbreaks of the western pine beetle and the California five-spined engraver.

To gain a better understanding of conditions that might be important, research workers started a study of climate and soil in relation to bark-beetle damage near Burney, California, in 1939. From this study they have found that the three most significant factors associated with tree mortality due to the western pine beetle are:

...precipitation during the spring months
...soil moisture in mid-July
...average daily temperature from April through July.

For the pine engraver, the two most significant factors proved to be:

...precipitation deficiencies from April to July
...the amount of breeding material left in areas logged during the spring months.

Ponderosa pine logging slash laid down in dry spring months may give rise to bark beetle outbreaks, unless loggers reduce the amount of material in which beetles can breed.

The practical significance of these findings lies in their application in anticipating and preventing bark-beetle outbreaks. It is not yet possible to manipulate climate so as to create conditions that will discourage the beetles. But our studies show that conditions favorable to outbreaks can be foretold by knowledge of air temperature, precipitation, and soil moisture.

Land managers can prevent outbreaks to some degree by management practices that reduce or eliminate the types of material in which pine engraver beetles breed. In some types of stands, such as young-growth ponderosa pine on the lower west slopes of the Sierra Nevada, pine engraver epidemics are a forerunner of the more destructive western pine beetle. These epidemics often stem from logging debris from cutting done during the spring and early summer months. Confining logging operations in such stands to late summer, fall, and early winter, utilizing trees to an 8-inch top diameter, and lopping and scattering limbs from unused parts of tree tops, are practices that will help reduce the chance of beetle damage in the reserve stand.

PHYSICAL PROPERTIES OF SPRAYS PROVE A KEY TO TOXICITY

In designing insecticides the old axiom--if a little is good, a lot is better--may not always work. Proof of this was turned up during the year in studies of the physical properties of residual sprays (compounds that leave on the treated surface a deposit of insecticide that remains deadly to insects for a long time).

For several years now we have been seeking information that will help us devise spray formulas most deadly to bark beetles--California's most destructive forest insects. We know that the effectiveness of these formulas depends a great deal upon the physical properties of the deposit they produce: the shape, size, and distribution of the crystals that make up the residue. So we are finding out which properties affect toxicity and how to control these properties. We do this by changing the physical state of a deposit and then measuring the mortality of beetles exposed to each state.

One of the most important factors we have found is the type of solvent in which an insecticide is dissolved. Some solvents produce deposits of crystals that are uniform both in structure and distribution over the treated surface. Others result in a spotty growth of crystals. Still others inhibit crystal formation altogether, sometimes making the chemical entirely unavailable to the insect.

One surprise finding is that the insects themselves may help make the deposits more deadly. Crystals grow poorly in certain formulas, but when insects walk over treated bark they often induce further crystallization. In tests with the California five-spined engraver, toxicity of DDT was greatly enhanced when test beetles were allowed to travel about on the treated surface. Crystals so formed are extremely fine and needle-like, and they appear to be more deadly than other types.

Some chemicals produce a very high kill after a very brief contact between the insect and the deposit. For example, with lindane, a chlorinated hydrocarbon, 0.01 ounce per square foot of bark killed 90 percent of the test beetles when they were confined on the treated surface for only 0.01 to 0.02 minute. But we were greatly surprised to find that increasing the dosage may diminish the effectiveness of such deposits. With DDT, for example, a deposit of 0.011 ounces per square foot was 10 times more potent to the test beetles than a deposit of 0.045 ounces. The difference in toxicity was clearly due to crystal form, which changes radically when the deposit is increased.

FOREST DISEASE RESEARCH

DISEASE RESEARCH ORGANIZED TO MEET INCREASED NEEDS

Late in August 1956 we set up a new Division of Forest Disease Research. This step centralized responsibility for all research on forest diseases in the Region. It will help meet the needs pointed out by Timber Resource Review and make the broadest possible use of a small roster of experienced personnel. The Blister Rust Control Methods Development Unit formerly responsible to the Regional Forester was transferred to the Station as the primary step in centralizing all disease research in this new division.

FOREST DISEASE SURVEY REVEALS TIMBER LOSSES

Our survey of forest tree diseases moved into its second year in 1956. This was the first full year of operation, and because survey crews covered more of the state than in 1955, they found more evidence of heavy losses in some areas. Among their findings:

- ... Losses from dwarfmistletoe in red fir and sugar pine are more severe and extensive than previously believed.
- ... Elytroderma needle disease is abundant and widespread and is causing considerable mortality in Jeffrey and ponderosa pines at several new locations in the state.
- ... The limb blister rust of Jeffrey pine, caused by Cronartium filamentosum, occurs over much of this tree's range and predisposes affected trees to beetle attack.
- ... White pine blister rust, though building up on sugar pine in northern California, has not yet been found farther south than Dodge Ridge in the central Sierra. Infection conditions were not favorable during 1956 for appreciable southward spread. The rust is creeping upward, however, into western white pine and whitebark pine at higher elevations in the north. Surveys of the disease's spread will be aided in the future by a new staining method of differentiating between pinyon rust and blister rust on ribes; field and laboratory tests showed that the method would be practical for field use by blister rust scouts.
- ... The rust witches broom in red fir, caused by Melampsorella cerastii, is common in the central and southern Sierra.
- ... On the east side of the Sierra Nevada, Fomes root disease increased mortality of ponderosa and Jeffrey pine reproduction.

Some new or unknown diseases attracted the attention of land managers and Station pathologists. They were: a needle blight of ponderosa pine in southern California, a dieback of bitterbrush in range lands of northeastern California, a dieback of madrone trees in Marin County, and a sooty mould on Douglas-fir in northwestern California. Pathologists, physiologists, and foresters of the University of California are helping us identify the causes.

Prompt detection and appraisal will help foresters do a better job of controlling forest tree diseases economically.

But they also need a yardstick to measure how their control work succeeds and where it is needed most. To provide this yardstick, we are studying disease conditions on a series of permanent sample plots throughout the commercial forests of the state. These plots will give foresters an inventory of tree diseases and a record of annual losses under natural conditions in all timber types and age classes. Our work in 1956 concentrated on perfecting methods, codes, and forms so that we can capitalize on the time and cost savings possible through use of punch cards and machine calculations.

CULL FACTORS TESTED IN SIERRA FIR STANDS

Studies completed during the year gave foresters an effective tool for estimating the amount of cull in fir timber in the Sierra Nevada. Some time ago we published cull factors for fir in northwestern California. These factors could be used to estimate the volume of cull material in trees that had conks or other external indicators of defect, but we were not sure how well they would work in other forest areas.

Station pathologists carefully dissected red and white fir trees in the central Sierra. They measured the defect and then compared the measured volume with estimates based on the published factors. For 300 dissected white firs, the estimate was within 1 percent of the measured cull; for 258 red firs, within 2 percent. These tests leave little doubt that the cull factors for red and white fir stands in northwestern California are equally valid in Sierra stands.

SPRAYS SOUGHT FOR DWARFMISTLETOE CONTROL

Forest pest surveys have emphasized the need for more rapid, cheaper control methods to cut down the enormous losses caused by dwarfmistletoe. The present method of control--cutting the infected branches or trees--is costly in commercial forests and undesirable in heavily infected recreation areas. In the search for better methods, we are testing selective sprays. We would like to find one that can kill the parasite but not the foliage of the host tree.

Guided by exploratory tests in other regions, we have selected eight chemicals for trial here. They were sprayed on young, heavily infected Jeffrey pines near Chilcoot, Plumas National Forest, in August and September 1955 and in May 1956.

Decayed wood in this dissected red fir is one type of defect measured in study of cull factors for Sierra Nevada timber stands.

Chemical sprays are being tested to see if they will kill dwarfmistletoe plants like these without damaging the pine branches where mistletoe grows.

When the 1955 tests were evaluated in August 1956, two chemicals showed some selectivity in toxic action on mistletoe and pine foliage: a carbamic acid derivative and an ester of 2, 4-D. They killed some mistletoe shoots and retarded others. Sprayed plants produced less seed than unsprayed ones. All the May 1956 treatments caused slight to severe injury to tree foliage. At least another year will be required to determine the extent of damage to the mistletoe parts embedded in the tissues of the host.

ECOLOGY STUDIES PROVE RIBES HARD TO ELIMINATE

The best way known to prevent serious losses of white pine from blister rust is to eliminate wild currants and gooseberries (Ribes). We have been checking their growth habits in sugar pine forests of the Sierra Nevada and in southern Oregon for several years. We have learned that most species of ribes are pioneer plants. Their seeds are surprisingly long-lived--seedlings continue to appear in slowly decreasing numbers for 20 to 30 years after eradication of dense groups of fruiting bushes. Ribes plants have a very high growth potential--on burns and other denuded areas their stems increased by leaps and bounds for a few years. And old, established plants are very persistent--they hang on in forest reproduction and in dense brush for years when new seedlings can not find a permanent place in the vegetation.

A study recently completed shows that large numbers of viable ribes seeds are stored in the duff and soil under virgin sugar pine forest on the west slope of the Sierra Nevada. The study also emphasized the severe competition from shrubs that tree seedlings may have to undergo on cutover or burned areas. We collected samples of the duff and soil, made germination tests with small concentrates of the samples, and counted the seedlings that appeared. The counts indicated these quantities of viable seeds per acre:

...currants and gooseberries--	16,000
...snowbrush and sweetbirch ceanothus--	1,865,000
...deerbrush ceanothus--	155,000
...manzanita--	10,000
...and many seeds of various other plants.	

Altogether nearly 3 million viable seeds were stored in 1 acre of the forest floor.

PELLETS MAY EASE RIBES CONTROL WORK

"Why don't they detach me from this long hose line and get rid of these heavy backpack tanks?" This is a common complaint of workmen who spray herbicides on ribes plants for blister rust control. The overburdened spraymen may soon be emancipated from some of their heavy duty tasks.

The emancipation comes in the form of special clay pellets. We have found that seedlings and crown sprouts of the Sierra Nevada gooseberry can be killed by scattering pellets impregnated with a readily volatile ester of 2, 4-D onto the soil about the base of these plants. The 2, 4-D pellets have been developed for blister rust control work in cooperation with the American Chemical Paint Company and have been under investigation for 4 years.

Control workers can carry these dry pellets in a paper or canvas bag and apply them easily and safely by hand. Savings on labor and equipment more than offset the high cost of chemical per treated plant. Some selectivity in killing action can be achieved because significant damage is generally confined to low-growing plants highly sensitive to light dosages of the vaporized 2, 4-D.

State regulations on the use of volatile esters of 2, 4-D (and similar herbicides) require that these pellets be used only under federal or state supervision in accordance with the general conditions of Bureau of Chemistry Announcement No. EP-88, September 5, 1956.

FUNGICIDES TESTED FOR BLISTER RUST CONTROL

Another new approach to blister rust control showed promise: using fungicides to protect both pines and ribes from infection by rust spores. In cooperation with the Pacific Northwest Forest and Range Experiment Station, we have tested Fermate, a well-known fungicide, at Wind River Nursery, Washington, for the protection of sugar pine seedlings. Sprayed and unsprayed pine seedlings were artificially exposed to rust infection for 48 hours. Comparison showed that Fermate resulted in a high degree of protection for the sprayed plants.

Tests of calcium sulfamate sprayed onto Sierra Nevada gooseberry in northern California indicated that this chemical acts as a systemic fungicide in preventing the infection of ribes by naturally deposited spores from pine cankers.

PROPAGATION AND TESTING OF RUST RESISTANT SUGAR PINE

In still another approach, we are propagating sugar pine trees believed to be resistant to blister rust. About 30 sugar pine seedlings were grafted at Berkeley and 35 at Union Creek Camp, Prospect, Oregon, with scionwood taken from two resistant sugar pines growing at the Supan Road infection center near Burney, California. These rust-resistant grafts will be transferred to test plantations in southern Oregon in early 1957. There they will be exposed to conditions highly favorable for rust development. About 350 sugar pine seedlings will be ready for grafting in the spring of 1957. Scionwood from other sugar pines apparently resistant to the rust will be used on some of these seedlings.

STUDIES OF HOW CLIMATE AFFECTS RUST EXPANDED

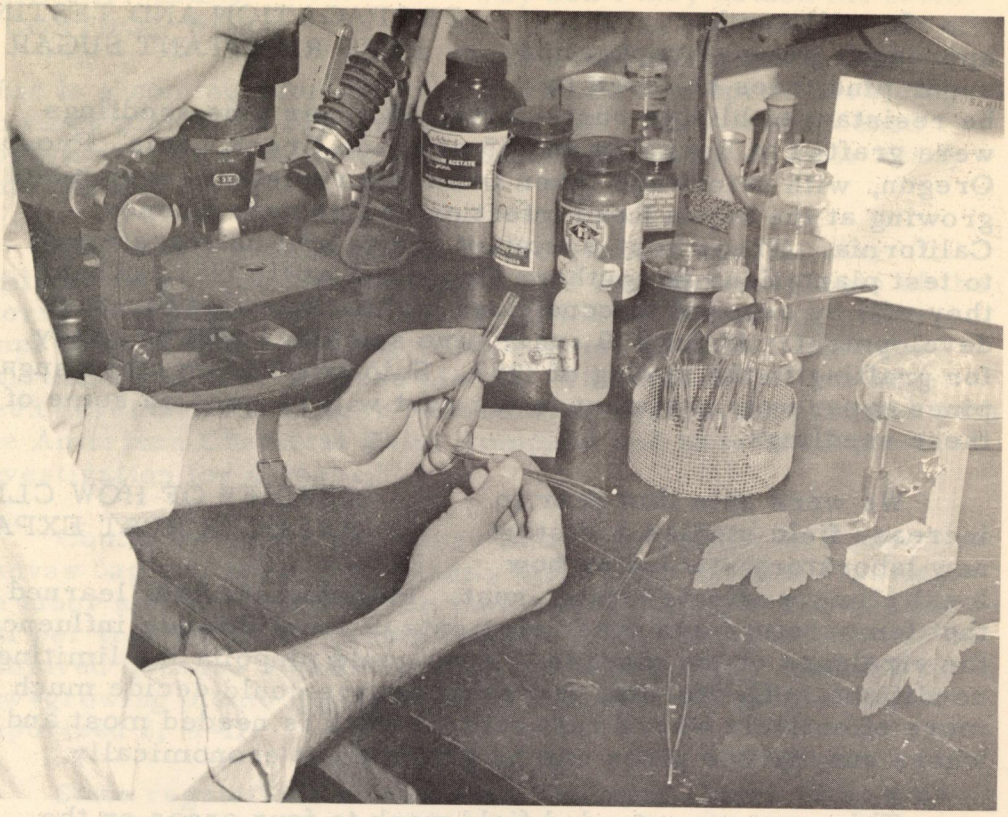
We were able this year to increase field studies and start new laboratory studies on how local climate affects blister rust. Pathologists have learned that temperature and other elements of local climate influence the virulence of the disease. If we could pinpoint the limiting conditions in California, forest managers could decide much more effectively where rust control work is needed most and where susceptible pines can be grown most economically.

This year we extended field work to four areas on the Plumas and Stanislaus National Forests. Three areas on the Plumas represent areas where the fungus:

...has intensified until 80 to 90 percent of the sugar pines are infected
...has been building up very slowly
...is confined to a small area and is not spreading.

The Stanislaus area represents the southern most invasion point of the fungus in California.

A new type of portable instrument shelter has greatly aided field measurements of temperature and humidity. The shelters are made entirely of aluminum, measure 9 by 12 by 20 inches, and weigh only 9-3/4 pounds. A man can carry three or four shelters with instruments inside over rough terrain. Titanium tetrachloride was used to provide visual evidence of the movement of air currents and the drift of sporidia--the spores that infect pines--around infected ribes bushes. This chemical forms a dense white smoke without heat of combustion when it is exposed to the air.



Pine needles and ribes leaves are inserted in specially designed vials holding nutrient solution for studies of rust fungus in climate-control chamber.

Laboratory studies are being conducted in the climate-control Mycotron of the Department of Plant Pathology, University of California. Here, temperature and humidity are controlled and the influence of each on the fungus is studied independently. We have developed new techniques for working with detached leaves of ribes and pine. The facilities permit us to study the effect of varying periods of heat, light, and humidity on sporidia production, life span, and behavior of the fungus.

INSTRUMENTS INSTALLED TO LEARN HEARTWOOD TEMPERATURE

What is the temperature deep in the heart of a Sierran white fir on a hot July day? Or on a chilly morning in the fall? Answers to these questions will give us clues to how fast decay-causing fungi spread in the heartwood. To find some of the answers, we have installed instruments in the middle Sierra Nevada that will provide a continuous record of the internal temperatures of

selected trees. The installations represent low, middle, and alpine elevational zones for white fir.

We plan to compare tree-temperature records with air temperatures at the same locations to determine the relationship between them. They will also be compared with the temperature-growth curve for the principal heartrot fungus in white fir, the Indian paint fungus. The final objective is to find out how elevation or other physical elements in the environment affect the rate of progress of heart rots in California timber.

The first charts show that the internal temperature of a tree responds only slowly and to a limited degree to air temperatures. For example, in July when air temperatures outside of a 36-inch diameter white fir near Camino, were showing a daily range of about 38°F. (62° to 100°F.), the heartwood temperature registered only a 2-degree change, from 62° to 64°F.

INTER-REGIONAL INTERESTS SERVED

Station pathologists have continued or completed several inter-regional assignments where mutual interests of California and other regions could be served. In blister rust control studies, we worked in southern Oregon with the Bureau of Reclamation, the Pacific Northwest Forest and Range Experiment Station, and the Rogue River and Umpqua National Forests. Three kinds of problems are under study there: Pine infection, ribes ecology, and the development of rust-resistant sugar pine. Cooperative studies with the Alaska Forest Research Center were concluded by publication of its Station Paper No. 6. This report provides information on the extent of decay and other defect in the vast timber stands of Southeast Alaska. Cull factors obtained from these studies will serve as a tool for estimating the defect in Sitka spruce, western hemlock, and western redcedar.

RANGE MANAGEMENT RESEARCH

NEW STAFF AND WORK CENTER STRENGTHEN RANGE RESEARCH

Range management research in the Station's territory was strengthened in 1956 by additions to the staff and by organizational changes. A wildlife research biologist transferred from the U. S. Fish and Wildlife Service to work on game-range studies and a range conservationist joined the organization at San Joaquin Experimental Range. Establishment of the Susanville Research Center improved the opportunities for more effective effort by bringing technical workers closer to field problems and the studies designed to provide answers to those problems. Considerable progress was made, cooperatively with the University of California, in starting new research at the San Joaquin Experimental Range on range fertilization and in developing long-range plans for a comprehensive range-livestock management research program on that area.

GRAZING USE SHOWS BENEFITS OF BRUSHLAND CONVERSION

Much of California's brushland range will produce more forage if the brush is replaced with grass. But even on the better land, a complete job of conversion is likely to take a lot of time and effort. A comparison of grazing use on brushland and converted range, however, has shown that the increased grazing values can quickly offset the costs of conversion.

Hereford yearling heifers were run on a 30-acre area of foothill brushland range for 135 days, April 17 to August 30, 1956. They gained 105 pounds on the average. The total grazing use on this area--which allowed 7.5 acres of range per heifer--was 540 animal days, or 18 days per acre.

On a nearby area of 106 acres, the brush had been removed by fire and sprouts and seedlings controlled by follow-up chemical spraying. There heifers gained 135 pounds. This area allowed only 4.4 acres per animal. During the 135-day season the heifers piled up 3,240 animal days of grazing use. This is 30.4 animal days per acre: 41 percent more grazing use than was obtained per acre of untreated brushland.

At an arbitrary value of $3.00 per animal month for grazing use, the benefits of brushland conversion would

warrant the expenditure of $1.24 per acre per year. Increased animal weight gains on the cleared range constitute another benefit of brushland conversion. Other benefits, such as improved soil-water relations and wildlife habitat values, increase the advantages of well planned, effective brushland conversion. The recommended procedure includes mechanical smashing of the brush followed by controlled burning, chemical spraying for sprout and seedling control, and seeding of forage species where necessary.

ECOLOGY STUDY REVEALS BITTERBRUSH SECRETS

Information underlying the successful use and management of bitterbrush ranges was developed in a new study started in 1956. This study is part of a project seeking ways to improve big-game ranges, in cooperation with the California Department of Fish and Game.

Bitterbrush, a valuable western browse species once believed to propagate almost entirely by seed, is now known as a sprouting, layering, seeding species. On one range site in Inyo County, we have found that about 20 percent of the bitterbrush plants resulted from stem layering. Many of these plants had become established several feet from the parent after the original stem had reached an age of 4 or more years. Root crown sprouting, on the other hand, occurs rather sporadically after fire. Seedling reproduction occurs irregularly on most sites and is closely related to rodent activity.

Bitterbrush does best, we have learned, on coarsely granular, friable, excessively drained soils having a neutral or slightly acid reaction. A shallow water table or clay pan or an alkaline soil reaction definitely restricts bitterbrush occurrence.

Severe losses of bitterbrush stands are occurring on important livestock and deer ranges in several northern California counties. This situation has been attributed to prolonged heavy use by grazing animals, destruction of plants by logging or fire, and adverse weather. Other factors, such as changes in soil reaction after fire and logging and the occurrence of a common oak root fungus, are undoubtedly additional contributing causes.

THIOUREA PLUS SPRING PLANTING BEST FOR BITTERBRUSH SEEDING

One early studies of bitterbrush showed that treating the seed with thiourea would break its dormancy. These results opened the door to successful spring planting, which had looked impractical because untreated seed would not germinate and stratified seed was too soft for mechanical seeders. But research workers suspected that thiourea might be toxic to bitterbrush seedlings, so they conducted planting tests in 1956 using both thiourea-treated and stratified seed.

In one test using seed treated 3, 4, and 8 minutes with a 3 percent thiourea solution and 30 minutes with a 1 percent solution, seedling emergence was 2 to 3 times better than from stratified seed. In another test seed treated 8 minutes with a 3 percent solution and 75 minutes with a 1 percent solution, produced two-thirds as many seedlings as stratified seed. Survival of seedlings from thiourea-treated seed was good; through the growing season the best lots did twice as well as those from stratified seed.

Project workers also compared seedling stands on pilot areas drilled in the fall of 1955 and the spring of 1956 in four widely spaced locations. They found that spring seeding consistently produced the best results. Untreated seeds were planted in the fall; thiourea-treated in the spring. There was no longer a question as to the superiority of spring planting or the non-toxicity of thiourea to bitterbrush seedlings.

BRUSH SPROUTS YIELD TO PERSISTENT TREATMENT

The removal and control of sprouting brush species is at best a difficult operation in the California foothill woodland type. Carefully handled, fire effectively removes dense stands of oak and other brush species, but it also stimulates sprouting. The result often is a denser stand of sprouting species than was present before burning. Re-burning controls seedlings but is usually wasteful and ineffective for sprout control.

Chemical herbicides sometimes do the job. Pilot tests of three common herbicides, started in 1953 and concluded in 1956, have shown the persistence of brush sprouts and the need for repeated treatments for effective control.

The herbicides tested included 2, 4-D, 2, 4, 5-T, and a combination of the two called "brushkiller." The cumulative percentages of plants killed were:

Chemical and brush species:	First year	Second year	Third year
2, 4-D			
Live oak	33	71	75
Blue oak	0	60	100
Redberry	57	57	86
Brushkiller			
Live oak	72	78	94
Blue oak	60	62	100
Redberry	41	76	100
2, 4, 5-T			
Live oak	51	81	97
Blue oak	31	37	87
Redberry	21	64	100

Only the third year results represent satisfactory control of the three species. One or two good applications may kill some plants, but satisfactory coverage of all plants requires three yearly sprayings. All three herbicides gave satisfactory control under these conditions, but brushkiller is recommended for a mixture of species. It is evident that spraying for sprout control the first, or the first and second years after burning in the woodland type will not do the job. Three consecutive treatments should be planned.

NEW STUDIES SEEK CONTROL OF CHAMISE

How to control chamise sprouts on areas burned at different times of year is the problem now being attacked on the Mendocino National Forest. Attention has been focused on this problem by the difficulty experienced in killing chamise sprouts on tractor ways, fire lanes, and other areas burned during early spring. This season often is a convenient and safe time for burning on national-forest lands. On game ranges, where chamise sprouts provide browse for deer, early spring burning has a place in range improvement, but until methods of killing the sprouts are developed, it will have only limited application on areas to be converted to grassland.

We hope to work out conversion techniques in this new study. One step will be to test burning at four different seasons: early spring, late spring, summer, and fall. The first chamise plot was burned in October 1956; the burning program will extend through 1959. For control of chamise sprouts and seedlings, we will test broadcast spraying and re-burning singly and in combinations. The test areas will be reseeded by a standard method of sowing, with a perennial grass mixture recommended jointly by state and federal workers in Station Research Note 111.

To see if better sowing methods or forage species can be found, we are setting up a series of small plots, where the Agricultural Research Service will test several new strains and species and develop new techniques for reseeding cleared brushland.

HEAVY RAINS MAY NOT BOOST HERBAGE YIELDS

Cattlemen who bank on heavy rains to insure bumper forage crops may be in for disappointment. This is the lesson from a recent study of rainfall and herbage production at the San Joaquin Experimental Range.

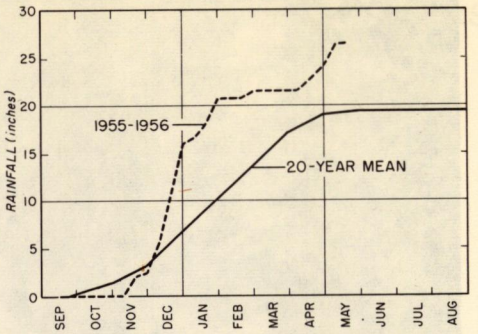
The heaviest rainfall since 1948 came in the 1955-56 rainy season: 26.45 inches. Yet the yield of herbage that year was the second lowest in the 8-year period. The highest yield was produced in 1950-51, which had 5 inches less rain. Rainfall and herbage yields in this period were as follows:

	Precipitation (Inches)	Herbage (Lbs./grazable acre)
1948-49	12.39	1,300
1949-50	16.00	2,300
1950-51	21.38	3,100
1951-52	24.69	2,200
1952-53	15.71	1,700
1953-54	15.58	2,400
1954-55	16.72	2,000
1955-56	26.45	1,600

The 1956 yield was only 300 pounds greater than the 1949 yield even though rainfall was more than twice as heavy.

How the rain was distributed made the difference. In 1955-56, 14 inches of the total fell between mid-December and the end of January. From then until April 12, only about 1 inch fell. Thus the critical period of plant growth was virtually without rain.

We can get an idea of what a favorable distribution looks like from the record of rainfall by 10-day periods during the past 20 years at the experimental range. This pattern requires fairly uniform spacing of rain in moderate amounts from October through April--without violent downpours in winter and critical deficiencies in spring. The seasonal average for 20 years was 19.4 inches. Uniformly distributed, less than the seasonal average, perhaps as little as 15 or 16 inches, would sustain high-level range herbage production on this foothill area.



Heavy 1955-56 rains were poorly distributed in comparison with long-time average.

WATERSHED MANAGEMENT RESEARCH

SNOW ZONE RESEARCH IN FULL SWING

Snowpack research in the high Sierra went into full operation this year to find practical ways to increase and prolong the yield of water from snow. This work is being done in cooperation with the California Department of Water Resources. A key center in the project is the Central Sierra Snow Laboratory formerly operated by the Corps of Engineers near Donner Summit. We have refurnished and expanded this field laboratory, mapped seven pine-fir watersheds in the headwaters of the American River, and started preliminary measurements of streamflow. Studies are underway to answer the following questions...

...What are the conditions of slope, direction of slope, and amounts and timing of watershed yield from various parts of the Sierra Nevada?

...How does snow accumulate and melt under different forest and slope conditions?

At the Central Sierra Snow Laboratory, research foresters--here weighing snow samples from forest and open areas--are seeking ways to improve water yield from snowpacks.

...What are the wind speeds and directions when snow falls? How does this affect snow drifting and accumulation?

...How and why does snow sometimes pack down and sometimes remain loose and fluffy, or assume certain other characteristics?

...What can be done to change its behavior--for example, to delay its melting?

...What is the climate during the period of these studies?

At a second work center, the Teakettle Snow Laboratory in the Kings River Basin, we are measuring water yield and sedimentation in five small watersheds. This will give us a check on their behavior before we start timber-cutting experiments. The Pacific Gas and Electric Company is assisting by servicing the streamflow recorders and measuring weather conditions and snow evaporation.

EROSION SOURCES PINPOINTED IN LOS ANGELES WATERSHED

Southern California mountains are infamous for their high erosion rates. Viewed from a plane or car, their rugged slopes and sparse vegetation make erosion control look like a herculean task. But a closer look--a study of soil movement in cooperation with the Los Angeles River Flood Prevention Project--has identified the most critical slopes and gives promise that the job may be cut down to reasonable size.

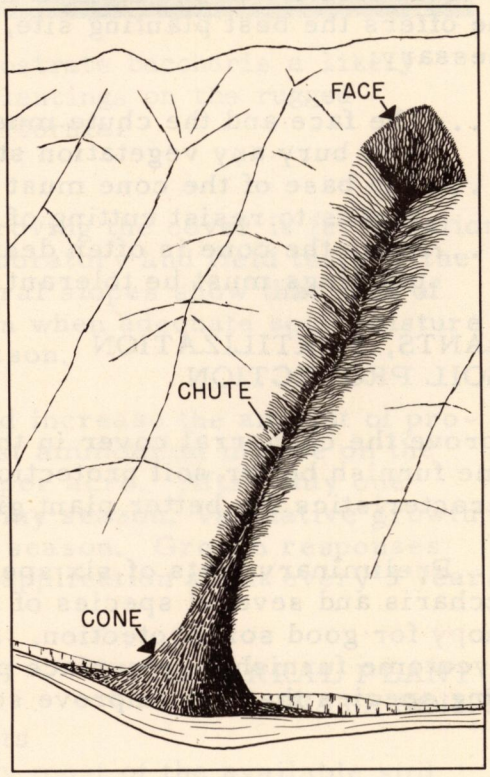
We have found that most of the erosion comes from a small fraction of this watershed--very actively eroding slopes that make up an estimated 10 percent of the area. It is on these slopes that measures for retarding debris movement should be concentrated.

The trouble spots are called rejuvenated slopes. These parts of the mountainsides are undergoing a new cycle of geological erosion caused by down-cutting of streams since the latest uplift of the mountain mass. Rejuvenated slopes have three major parts:

The face is the cliff-like area at the head of a slope. It is above the angle of repose and often approaches the vertical. Faces range in height from less than a foot to many hundreds of feet and are the most rapidly eroding areas in the watershed.

The chute is the steep slope beneath the face down which the debris slides toward the stream channel.

The colluvial cone is the accumulated soil and rock material at the foot of the slope. The base of the cone usually rests in a watercourse, and debris extends up the slope at the angle of repose.



The actively eroding face and the toe of the cone are the main sources of debris. Debris is continually falling off the face and away from the root systems of the plants. This action continues until the plants above the face are undermined and fall into the chute. Rocks and soil continually move down the chute. Even during the dry season the debris is carried from the face to the cone by gravity. A man standing near these slopes can actually hear the erosion. Measurements have shown that the amount of dry-season soil movement was nearly as great as the rainy season water-activated movement. This comparison, however, was obtained during a series of years with low rainfall and does not represent the erosive action from prolonged and violent storms.

Erosion control on faces and chutes is a real problem, but some progress has been made. Small faces 5 to 6 feet high have been successfully stabilized by the Angeles National Forest Flood Control Project. Wire screen barriers staked along contours retained pockets of soil where plants can be established to extend their protective cover over adjacent areas. Similar measures can be used on chutes.

Stabilization of the cone is more complicated. Although the cone offers the best planting site, three special measures are necessary:

- ...The face and the chute must be stabilized or their debris will bury any vegetation started on the cone.
- ...The base of the cone must be stabilized by mechanical means to resist cutting of the toe by streamflow.
- ...Since the cone is often deep in the canyon, stabilization plantings must be tolerant to shade.

NEW PLANTS, FERTILIZATION AID IN SOIL PROTECTION

Plants from climates similar to that of southern California can be used to improve the chaparral cover in the southern California mountains. Some furnish better soil protection; others improve the soil characteristics for better plant growth.

Preliminary tests of six species are promising. Prostrate baccharis and several species of rock rose produce a dense canopy for good soil protection. Spanish broom and hairy calycotome furnish less surface protection but are nitrogen-fixing species that can improve soil quality.

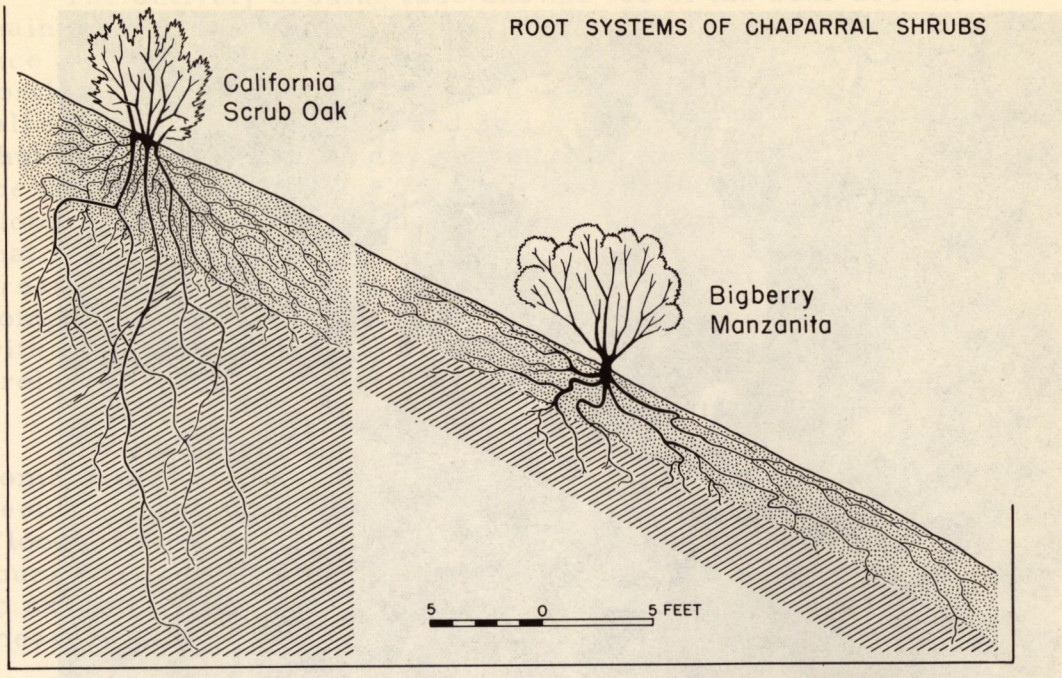
Low, spreading branches make prostrate baccharis a likely candidate for erosion-control plantings on the rugged mountain slopes of southern California.

Another possiblity for improving the cover is fertilization of critical watershed soils. Laboratory and field tests in the more sparsely vegetated chaparral slopes show that lack of nitrogen limits plant growth even when adequate soil moisture is available during the rainy season.

To see if fertilization would increase the amount of protective plant cover, we broadcast ammonium nitrate on the slopes at the rate of 100 pounds per acre. After only one application at the start of the rainy season, vegetative growth nearly doubled the next growing season. Growth responses as time passed indicate that re-application about every 3 years would be necessary.

CHAPARRAL PLANT ROOTS DOMINATE SOIL SPACE

One reason for sparseness of cover on many southern California mountains is that roots of native chaparral plants occupy most of the available soil



space, including the soil not covered by the canopy of trees and shrubs.

Root systems of 18 species of shrubs were studied in cooperation with the Angeles National Forest on the Los Angeles River watershed. Some plants like bigberry manzanita were shallow rooted; others like scrub oak sent roots into soil and rock as deep as 28 feet. As a group, the various species occupied practically all the soil space.

Thus, we can see one reason why it is so difficult to interplant more desirable species on these slopes, and why it is necessary to kill the existing vegetation, even though sparse, before new plants can be grown.

WATER YIELD INFLUENCED BY TYPE OF VEGETATION

How do trees, grass and brush affect runoff? infiltration? water yield? Eighteen years ago, 26 large concrete lysimeter tanks, 6 feet deep, were installed on the San Dimas Experimental Forest, where we are seeking answers to these questions with the cooperation of the California Division of Forestry. The tanks were filled with

local mountain soil and checked for uniformity for several years. In 1946, pure stands of native shrubs and pine were planted on all but one tank which was kept bare for control. Then, in 1952, two of the shrub tanks were planted to native bunchgrasses. Surface runoff, infiltration, seepage, and moisture stored in the soil were measured.

The results of the past 4 years, during which rainfall has averaged 6 inches below the 27-inch normal, show the influence of vegetation.

The greatest water yield came from the bare plots--but entirely in the form of surface runoff. Here runoff was more than twice that of the vegetated plots. Infiltration into the bare soil was only 37 percent of the rainfall; under the vegetation it varied from 75 to 84 percent. Evaporation and transpiration losses each year used essentially all the available soil moisture in the tree, and shrub-covered plots. Only under the grass was the full 6 feet of soil wet to field capacity and ground water yield produced.

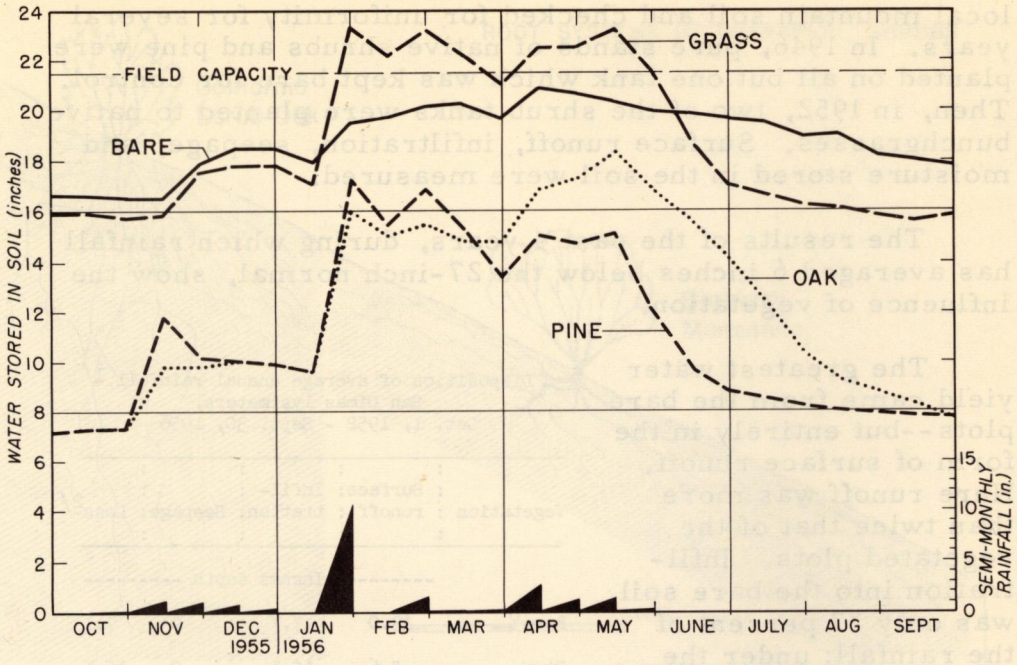
Disposition of average annual rainfall,[1] San Dimas lysimeters, Oct. 1, 1952 - Sept. 30, 1956

Vegetation	Surface runoff	Infiltration	Seepage	Loss[2]
	----------Inches depth ---------			
Bare	13.0	7.7	0	7.1
Pine	5.6	15.1	0	15.1
Chamise	4.1	16.6	0	16.5
Grass	4.0	16.7	1.7	15.3
Buckwheat	3.5	17.2	0	17.2
Scrub Oak	3.3	17.4	0	17.5

[1] Average = 20.7 inches; range, from 16.01 to 25.39 inches

[2] Loss = Rainfall-(runoff + seepage - increase or + decrease in soil moisture storage during period). Includes evaporation from soil, transpiration, and interception loss.

The amount of water in the soil under bare and vegetated conditions differed markedly during a typical low rainfall year. Soil moisture varied least in the bare soil. Here, infiltration was least, and water was lost only through evaporation. Infiltration under the oaks was greatest, but evapotranspiration losses also were the highest. Consequently, moisture in the soil under oaks varied most.



Seasonal variations of water in lysimeter soil, 1955-56. (Field capacity is the amount of water the soil will hold when drained.)

Results during the last 4 years have shown that...

...Water yield was entirely surface runoff in these dry years except for a small amount of seepage under grass cover.

...Runoff was somewhat greater from the pine-and grass-covered soils than from shrub cover, but only half that from bare soil.

...All the available soil moisture under the shrub and pine was lost to evapo-transpiration during each summer dry season, whereas, about 10 inches of water still remained in the bare and grass-covered soils.

...Pine and grass dried the soil more rapidly during the winter and spring than did the scrub oak.

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Blaisdell, James A., and Hubbard, Richard L.
An "outrigger" type deer fence. Calif. Forest and Range Expt. Sta. Res. Note 108. 3 pp., illus.

A new type of deer fence has possibilities as a cheap substitute for standard, woven-wire deer fences 8 to 9 feet high.

Biswell, H. H., and Graham, Charles H.
Plant counts and seed production on California annual-type ranges. Jour. Range Mangt. 9(3):116-118.

Abundant seed is produced each year even under rather close cattle grazing on annual-type foothill ranges. In this type 15 to 20 forage species per square feet are common. Four important annual species produced from 1,000 to 15,000 seedlings per square foot. About half grew to maturity.

Buttery, Robert F.
Range conditions and trends resulting from winter concentrations of elk in Rocky Mountain National Park, Colorado. Jour. Range Mangt. 9(3):148. (Abstract)

Reports range conditions and trends in condition observed by the line-intercept and Parker three-step methods on two concentration areas of elk winter range.

Callaham, R. Z.
Needle oils of three pine species and species hybrids. Forest Science 2(2):101-105.

No striking differences between species were found. Oils of hybrids had properties intermediate between those of the parents.

Chandler, Craig C.
Integrating prevention into fire control planning. Fire Control Notes 17(2):6-7.

Suggests need for major re-evaluation of fire-control planning methods in order to integrate fire prevention in organization plans.

Countryman, C. M.
Fire season severity in 1955 on the Klamath National Forest. Calif. Forest and Range Expt. Sta. Res. Note 103. 7 pp., illus.

Weather conditions in 1955 produced the most severe burning conditions ever experienced on the Klamath National Forest. Shows how a severity index can be computed and suggests that the worst possible burning condition has not yet been reached.

Countryman, C. M.
Old-growth conversion also converts fireclimate. Soc. Amer. Foresters Proc. 1955:158-160, illus.

Cutting a forest stand changes the local fire weather and therefore changes the fire-control job.

Eaton, C. B.
Jeffrey pine beetle. U. S. Dept. Agr. Forest Pest Leaflet 11. 7 pp., illus.

Describes a pest destructive to Jeffrey pine timber in California. Tells how to recognize the insect and its damage; outlines life history and habits; explains preventive control through selective logging and methods of applied control.

Ely, Joseph B., and Jensen, Arthur W.
Air delivery of water helps control brush and grass fires. Fire control Notes 17(2):22-25.

Describes tests of crop-duster plane equipped as an air tanker for close support of ground fire-fighting forces.

Firestop
Backfire line with chemicals. Progress Report 13. 6 pp., illus. (Prepared by the Station fire research staff for the Firestop Executive Committee.)

Describes a method of smashing brush with a tractor and then spraying a chemical retardant to prepare emergency backfire line in brush fuels.

Firestop
The wind survey. Tech. Report 2. 18 pp., illus. (Prepared by DeVer Colson, U. S. Weather Bureau, and the Station fire research staff for the Firestop Executive Committee.)

Describes procedures and instrumentation developed for a 3-month intensive study of air movement in a typical mountain canyon. Recommendations are given for future wind surveys.

Ford, Donald H., and Rawlins, T. E.
Improved cytochemical methods for differentiating Cronartium ribicola and Cronartium occidentale on Ribes. Phytopath. 46(12):667-668.

Describes field method for differentiating between pinyon rust and white pine blister rust. (Cooperative study by University of California.)

Fowells, H. A., and Schubert, G. H.
Seed crops of forest trees in the pine region of California. U. S. Dept. Agr. Tech. Bul. 1150. 48 pp., illus.

Summarizes 28 years of seed production of sugar pine, ponderosa pine, and white fir, chiefly on the Stanislaus National Forest. This information has been interpreted for application to cutting practices and seed collection.

Fowells, H. A., and Schubert, Gilbert H.
Silvical characteristics of sugar pine. Calif. Forest and Range Expt. Sta. Tech. Paper 14. 19 pp., illus.

Summarizes the silvical information on sugar pine. The report includes a description of the species, its habitat conditions, and growth habits.

Gardner, R. A.
Soil-vegetation surveys as an aid in range management. Soc. Amer. Foresters Proc. 1955:37-39.

Points out some of the specific uses of soil-vegetation surveys for range management and range research.

Gordon, Donald T.
Slash disposal and seedbed preparation by tractor. Jour. Forestry 54(11): 771-773.

Reports methods used and costs at Blacks Mountain and Stanislaus Experimental Forests. At Blacks Mountain, satisfactory work cost $46.00 per acre of regeneration area, $1.20 per acre for gross area logged, and $0.24 per thousand board-feet of timber harvested.

Hallin, William E.
Planting ponderosa pine is a good investment. Calif. Forest and Range Expt. Sta. Res. Note 104. 5 pp.

Estimates the present worth at different rates of interest for ponderosa plantations on sites ranging in productivity from poor to excellent. For example, on Site Index 100 with an interest rate of 4 percent, the value at time of establishment is $78 per acre.

Hallin, William E.
Pruning ponderosa and Jeffrey pine. Calif. Forest and Range Expt. Sta. Res. Note 115. 4 pp.

Shows the maximum heights to which ponderosa pine crop trees may be pruned at different stand densities and tree diameters.

Hellmers, Henry, and Machlis, Leonard
Exogenous substrate utilization and fermentation by the pollen of Pinus ponderosa. Plant Physiol. 31(4):284-289.

Presents data on food reserves, their rate of use during germination, and the effect of various metabolic inhibitors. Germinating pollen was found to absorb and metabolize externally supplied carbohydrates.

Hormay, A. L.
How livestock grazing habits and growth requirements of range plants determine sound grazing management. Jour. Range Mangt. 9(6):161-164, illus.

Studies on mountain ranges in the pine timber and grassland of northeastern

California show that selective grazing by livestock is a main cause of range deterioration. Some form of rest-rotation grazing is needed to help restore range production.

Hubbard, Richard L.
Bitterbrush seedlings destroyed by cutworms and wireworms. Calif. Forest and Range Expt. Sta. Res. Note 114. 2 pp.

Cutworm and wireworm damage was found a threat to bitterbrush reseeding in northeastern California. Ninety-eight percent of the emerged seedlings were killed by cutworms at one place.

Hubbard, Richard L.
Effect of depth of planting on the emergence of bitterbrush seedlings. Calif. Forest and Range Expt. Sta. Res. Note 113. 6 pp., illus.

Two inches seems about the maximum depth from which bitterbrush seedlings can be expected to emerge. The best emergence is from seed planted 0.5 to 1.5 inches deep, depending on soil-moisture conditions.

Hubbard, Richard L.
The effects of plant competition upon the growth and survival of bitterbrush seedlings. Calif. Forest and Range Expt. Sta. Res. Note 109. 9 pp., illus.

Seedbed preparation, alone and with subsequent weeding, increased seedling growth of bitterbrush and reduced mortality. Three-year-old seedlings averaged 4.5 inches high under native vegetation, but 26.0 inches on a plowed and weeded area.

Kimmey, J. W.
Cull factors for Sitka spruce, western hemlock, and western redcedar in Southeast Alaska. Alaska Forest Res. Center Sta. Paper 6. 31 pp., illus.

Provides a tool for estimating defect, through the application of cull discount factors, in the commercial timber stands of Southeast Alaska.

LeBarron, Russell K.
We can have sugar pine--without fire. Sierra Club Bul. 41(10):84-86.

Concludes that sugar pine owes it perpetuation primarily to such qualities as long life and large size. Points to the need for blister rust control and planting of old burns and cutovers.

Liddicoet, A. R.
Humidity control unit for greenhouses and propagating beds. Calif. Forest and Range Expt. Sta. Res. Note 112, 3 pp., illus.

Describes construction and operation of an inexpensive control unit used at the Institute of Forest Genetics.

May, R. H.
Wood leftovers could mean new industries. The Ukiah News, Logging Edition, May 24, 1956, Sec. 3:5, 8.

Presents statistics on logging and milling residues in the Redwood Region and points out opportunities for using this material for fiber production.

Miller, Harry R.
Chemical fire retardants for wild land fire control. Calif. Forest and Range Expt. Sta. Res. Note 105. 5 pp.

Describes tests using sodium calcium borate as a fire-retarding chemical during 1955 fire season. Includes conclusions and recommendations. (Also in Fire Control Notes 17(4):25-28.)

Mirov, N. T.
Photoperiod and flowering of pines. Forest Science 2(4):328-332, illus.

Pines performed not as long-day or short-day plants, but as neutral ones whose flowering is not affected by length of day.

Mirov, N. T.
Composition of turpentines of lodgepole and jack pine hybrids. Canad. Jour. Bot. 34:443-457, illus.

Jack pine (bicyclic) terpentines dominated over lodgepole (monocyclic) turpentines in both artificial and natural hybrids.

Mirov, N. T., and Iloff, P. M., Jr.
Composition of gum turpentines of pines, XXV. A report on two white pines: Pinus koraiensis from Korea and P. peuce from Macedonia. Jour. Amer. Pharm. Assoc., Sci. Ed. 45(2):77-81.

Turpentines of both pines contained large amounts of diterpenes.

Mirov, N. T., and Iloff, P. M., Jr.
Composition of gum turpentines of pines, XXVI. A report on Pinus lawsoni and P. herrerai from Michoacan, Mexico, and P. ponderosa from the California coast. Jour. Amer. Pharm. Assoc., Sci. Ed. 45(3):153-156.

Turpentine of ponderosa pine from the Santa Cruz Mountains possessed some characters found in that of Coulter pine.

Mirov, N. T., and Iloff, P. M., Jr.
Composition of gum turpentines of pines, XXVIII. A report on Pinus edulis from eastern Arizona, P. tropicalis from Cuba, and P. elliottii var. densa from Florida. Jour. Amer. Pharm. Assoc., Sci. Ed. 45(9):629-634.

A new chemical compound, never previously reported in any plant, was discovered in the turpentine of pinyon.

Nord, Eamor C.
Quick testing bitterbrush seed viability. Jour. Range Mangt. 9(4):193-194, illus.

Describes a four-step procedure for determining viability of bitterbrush seed.

Poli, Adon
Ownership and use of forest land in northwestern California. Land Econ. 32(2):144-151, illus.

Summarizes and interprets results of forest land ownership studies in the northern coastal counties of California. (Cooperative study with Agricultural Research Service.)

Roy, D. F.
Killing tanoak in northwestern California. Calif. Forest and Range Expt. Sta. Res. Note 106. 9 pp., illus.

Small tanoak trees were killed with basal hormone sprays but large trees resisted the treatment. Effects of frilling were delayed, but tree vigor decreased and trees will eventually die. Tanoak sprouts were eliminated by late fall applications of 2, 4-D or 2, 4, 5-T.

Roy, D. F.
Salvage logging may destroy Douglas-fir reproduction. Calif. Forest and Range Expt. Sta. Res. Note 107. 5 pp., illus.

Salvage of fire-killed Douglas-fir timber in northwestern California destroyed about 80 percent of the 2,000 Douglas-fir seedlings per acre which were present before logging. Damage to reproduction can be reduced by careful, prompt logging.

Roy, D. F.
Big Douglas-fir in northern California. Western Conserv. Jour. 12(4):37, illus.

A 38 foot log, 91 inches in diameter at the small end and 103 inches at the butt, contained a gross volume of 15,580 board-feet, 13,840 net. Annual rings counted on the butt totaled 763. Radial growth was fast for the first 100 years and did not decrease rapidly until the tree was over 350 years old.

Roy, D. F.
Research in the redwood region. The Ukiah News, Logging Edition, May 24, 1956, Sec. 4:8.

Summarizes forest management research activities in the redwood--Douglas-fir region. Lists some of the problems facing the managers of timber lands which can be answered by research.

Schubert, Gilbert H.
Effect of ripeness on the viability of sugar, Jeffrey, and ponderosa pine seed. Soc. Amer. Foresters Proc. 1955:67-69, illus.

Immature sugar and Jeffrey pine seeds produced abnormal seedlings. None of the immature ponderosa pine seeds produced abnormal seedlings; however, germinative capacity was considerably lower than for mature seeds.

Schubert, Gilbert H.
California cone crop--1956. Calif. Forest and Range Expt. Sta. Res. Note 110. 5 pp., illus.

The cone crops of most commercial forest trees in California were generally good for the first time in several years throughout the state. Of the major species, incense-cedar was the only one with no cones throughout most of its range.

Schubert, Gilbert H.
Effects of fertilizer on cone production of sugar pine. Calif. Forest and Range Expt. Sta. Res. Note 116, 4 pp., illus.

Fertilization with ammonium phosphate increased sugar pine cone production. During a 4-year period the fertilized trees produced nearly three times as many cones as the unfertilized trees.

Schubert, Gilbert H.
Early survival and growth of sugar pine and white fir in clear-cut openings. Calif. Forest and Range Expt. Sta. Res. Note 117. 6 pp., illus.

Clear-cut openings were found to favor sugar pine over white fir seedlings. More white fir than sugar pine seedlings were killed or damaged by freezing and browsing. As a result sugar pine has a head start in the race for dominance.

Shifrine, M., and Phaff, H. J.
The association of yeasts with certain bark beetles. Mycologia 48(1):41-55.

Describes 169 isolations of yeast found occurring in several western species of bark beetles and discusses certain typical physiological properties of these yeast isolates. (Cooperative study by University of California.)

Short, L. R., and Woolfolk, E. J.
Plant vigor as a criterion of range condition. Jour. Range Mangt. 9(2):66-69, illus.

Demonstrates the soundness of the vigor concept and shows how it can be used almost any time of year on northern Plains range to indicate current range conditions.

Smith, R. H.
The rearing of Lyctus planicollis and the preparation of wood for control tests. Jour. Econ. Ent. 49(1):127-129.

Oak and hickory limbwood, cut during the dormant season of growth and seasoned rapidly, was found best for rearing the beetle in large numbers for test purposes.

Smith, R. H.
Lyctus powder-post beetle control by surface application of oil preparations and solvents. Pest Control 24(4):42-45, illus.

Describes several control methods, of which trichlorobenzene and Velsicol AR-50 were significantly more effective than other preparations.

Smith, R. H.
A technique for studying the oviposition habits of the southern lyctus beetle and its egg and early larval stages. Jour. Econ. Ent. 49(2):263-264, illus.

Discusses the technique of exposing several springwood vessels along the tangential surface of hickory and then tightly covering them with glass to provide observation "windows."

Stone, Edward C., and Schubert, Gilbert H.
New roots on pine seedlings. Calif. Agr. 10(3):11, 14, illus.

Reports preliminary results of a study to determine the factors affecting new root growth on ponderosa pine transplants. Trees transplanted in April produced more and longer roots than stock planted in October or November.

Tevis, Lloyd, Jr.
Invasion of a logged area by golden-mantled squirrels. Jour. Mammal. 37(2):291-292.

Though golden-mantled squirrels generally avoid dark virgin forests, some individuals migrated through 2-1/2 miles of continuous virgin timber into cut-over land, where they established themselves and multiplied. (Cooperative study by University of California.)

Tevis, Lloyd, Jr.
Responses of small mammal populations to logging of Douglas-fir. Jour. Mammal. 37(2):189-196.

White-footed mice and Townsend chipmunks became numerous after logging. They, and the chickaree, destroy large amounts of tree seed. (Cooperative study by University of California.)

Tevis, Lloyd, Jr.
Behavior of a population of forest-mice when subjected to poison. Jour. Mammal. 37(3):358-370, illus.

A population of bait-shy mice can be developed to protect untreated seed from mice if proper procedures are employed. (Cooperative study by University of California.)

Tevis, Lloyd, Jr.
Effect of a slash burn on forest mice. Jour. Wildlife Mangt. 20(4):405-409, illus.

Slash burning did not control mice. It killed or drove out all but a few, but the area was heavily reinvaded in 2-1/2 weeks. (Cooperative study by University of California.)

Tevis, Lloyd, Jr.
Pocket gophers and seedlings of red fir. Ecology 37(2):379-381.

Overgrazing, pocket gopher activity, and a bumper crop of red fir seed worked together and allowed red fir to invade a turf of Idaho fescue. (Cooperative study by University of California.)

Quick, Clarence R.
Viable seeds from the duff and soil of sugar pine forests. Forest Science 2(1):36-42.

Reports the kinds and quantities of viable seeds recovered from 64 duff and soil samples collected under certain timber stands.

Quick, C. R., and Burrill, W. S.
Research Progress Report. Additional results from herbicide tests on ribes in California. Res. Comm. Western Weed Control Conf. 1956:41-42.

Summarizes results in 1955 from field tests of chlorinated phenoxy herbicides and other chemical weedkillers on Sierra Nevada gooseberry.

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